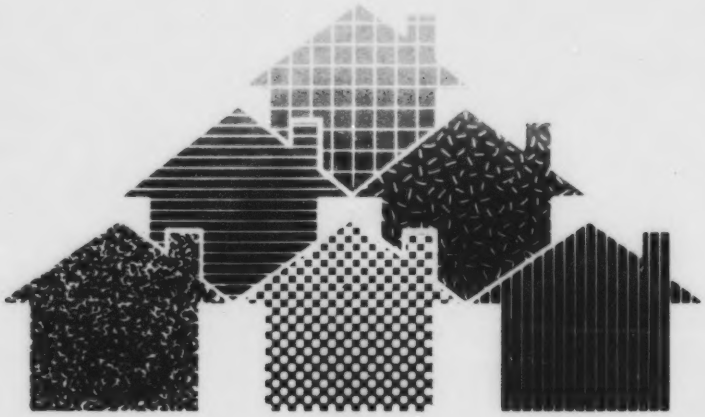
Whole House Retrofit Techniques



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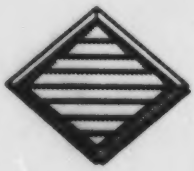
Whole House Retrofit Techniques



A Manual Prepared for

Natural Resources Canada (NRCan)

by

REIC Ltd.

Canadian Cataloguing in Publication Data

Main entry under title:

Whole house retrofit techniques: a manual

Issued also in French under title: Techniques synergétiques résidentielles.
Previously published: Energy, Mines and Resources Canada, Home Energy Programs, 1987.
Includes bibliographical references.
ISBN 0-662-15646-3
Cat no. M91-9/1-1987E

1. Dwellings — Energy conservation.
2. Dwellings — Canada — Energy conservation.
I. REIC Ltd. II. Canada. Efficiency and Alternative Energy Branch.

TJ163.5D86W83 1994 693.8'32 C94-980098-8

©Minister of Supply and Services 1987
Reprinted February 1994

Cat. No. M91-9/1-1987E

To receive additional copies of this free publication, write to:
Energy Publications
c/o Canada Communication Group
Ottawa, Ontario
K1A 0S9

Facsimile: (819) 994-1498

Aussi disponible en français sous le titre «Techniques synergétiques résidentielles»
N° de catalogue : M91-9/1-1987F

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The successful production of this report would not have been possible without the technical comments and opinions of those listed in Appendix E. Natural Resources Canada acknowledges their contribution with thanks.

Acknowledgements

This manual was developed by REIC Ltd. of Toronto. French translation was provided by Les Traductions Translex Inc. The authors also wish to acknowledge with thanks the assistance provided by various other individuals. Their names are listed in Appendix E.

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1

OVERVIEW

This manual has been developed to serve as a reference for Canadian contractors interested in pursuing major energy retrofit opportunities for existing homes.

The information presented throughout the manual is intended as a guide. The authors are not presenting prescriptive measures which will have universal application. Instead, the manual provides a framework within which the reader can make decisions based on a better understanding of the theoretical, technical, and pragmatic implications of 'total retrofit' work.

The construction techniques presented in the manual represent techniques which have been used by various contractors throughout the country. These details have all been tried, although few may have been fully tested, monitored and evaluated. The number of different approaches to 'total retrofitting' which have been used throughout the country reflects the range of options available. Different approaches will be used by different contractors in response to regional fuel prices, labour and materials availability and the demands of the specific marketplace. This manual can be seen as a documentation of the evolutionary state of the industry at this time.

Before launching into detailed technical discussions about whole house retrofit techniques, this chapter will place the 'total retrofit' within context. Chapter One provides an overview of the concepts promoted throughout the manual and establishes a broad framework within which specific decision-making can take place.

1.1 WHAT IS TOTAL RETROFIT?

Throughout this manual the terms 'total retrofit' and 'whole house retrofit' are used interchangeably to describe **a major upgrading of the energy performance of an existing house.** This manual will present information on all aspects of a 'total retrofit', the rationale for such extensive work, how to perform the different tasks, and the implications of the work.

The manual refers to total retrofit measures more as an approach than as a specific system. This focus on approach will allow the contractor to relate the different elements of the job most closely to the specific requirements of his climate, housing stock and, most importantly, clientele.

The terms 'whole house retrofit' or 'total retrofit' do not impose specific prescriptive or performance-related requirements on any house. Instead, the specific elements of the retrofit: the overall reduction in fuel consumption, the upgraded insulation levels and improved air tightness, etc., will vary from region to region, from house to house and from homeowner to homeowner.

While the total retrofit will be designed differently for each and every house, several characteristics of the work will typify the approach.

- **High Insulation Levels** - The retrofit will incorporate high levels of insulation relative to conventional renovation work. Also, the insulation should be installed to prevent air circulation and to reduce thermal bridging.

- **Air Tight Construction** - The retrofit will concentrate on reducing the uncontrolled movement of air through the building envelope. A continuous air barrier will provide the homeowner with a draft-free, structurally sound building.

- **Moisture Control** - The retrofit will incorporate a vapour barrier on the house interior to restrict the flow of water vapour. On the exterior, the retrofit will restrict air and water penetration into the envelope with the careful installation of flashings and sheathings.

- **Controlled Ventilation** - The retrofit will provide the homeowner with high levels of air quality by incorporating a controlled ventilation strategy. The ventilation system will provide fresh air to all areas of the house.

- **Safe and Efficient Heating Systems** - The retrofit will include an upgrading of the existing heating system. This may involve improving combustion efficiency or installing a new high-efficiency furnace. Combustion air requirements will be satisfied. The heat distribution system of the house will be 'tuned' to meet the new demands of the upgraded house.

The total retrofit represents a new approach to home renovation which can result in a new look for the house and improved performance. The end result can be a house which is equivalent to the standards prescribed for new energy-efficient homes.

The successful retrofit contractor will have considered the following aspects:

- The house will be dealt with as a system. The contractor will have gained an understanding of the effect that major renovation and retrofit activities will have on house operation.

- Building science issues which come into play when renovating will have been considered, ensuring that retrofit elements will perform correctly - thermally and structurally.

- The retrofit measures will have been designed in a planned and coordinated manner, taking advantage of any or all renovation-related activities.

1.2 WHY RETROFIT?

Before detailing the principles and techniques employed in energy-efficient retrofit work, it is useful to examine the rationale behind total retrofit projects. There are three major reasons for retrofitting:

- to save energy and fuel dollars;
- to improve comfort levels in the home; and
- to tie in with ongoing renovation work.

Most homeowners will be guided in their decision making by a combination of the above mentioned factors.

Retrofitting to Save Energy

Some homeowners undertake major retrofit activities in an effort to reduce energy consumption and the operating expenses of heating and cooling the home. The retrofit will reduce energy consumption and fuel costs by:

- reducing conductive heat losses;
- reducing heat losses associated with excessive rates of air change;
- improving the performance of the heat distribution system; and
- improving the efficiency of the heating unit.

The whole house retrofit will result in significant reductions in fuel costs. The amount of reduction will be dependent on the housing type, the retrofit techniques employed, and the homeowner's lifestyle and operating habits. Chapter 5 of the manual looks at means of assessing the financial costs and potential benefits of total retrofit work.

Retrofitting to Improve Comfort Levels

Improving comfort levels within the house ranks as a major factor in the decision to retrofit. While benefits such as increased comfort are difficult to quantify or analyze on a cost/benefit basis, the improved performance of the energy-efficient house is more commonly referred to in terms of comfort – not necessarily in terms of dollars saved.

The total retrofit will result in major improvements to comfort levels within the structure including the following:

Reduced Drafts - The major focus on air tightness during the retrofit process will result in fewer cracks, penetrations and holes in the envelope which allow cold winter air to leak into the house and heated air to escape to the outside. Homeowners are expecting improved comfort levels, especially in newer homes. The "draft-free" nature of the upgraded house is a major selling feature.

Higher Humidity Levels - The increased air tightness of the building will result in more comfortable humidity levels as air changes will be controlled not accidental. Control over humidity levels will be provided by a mechanical ventilation system which forms an integral part of the retrofit.

Enhanced Air Quality - The mechanical ventilation system will ensure greater control over the rate of air change in the building. The system will allow the homeowner a continuous supply of fresh air to all areas of the house.

Even Heat Distribution - A total retrofit will allow a more uniform and comfortable flow of heat throughout the building. The upgraded thermal envelope and improved air distribution systems should result in reduced temperature stratification and a more uniform distribution of heat in the building.

Quieter Interior - The higher insulation levels and tighter building envelope will buffer the house interior from outside sound, resulting in a much quieter home.

Retrofitting as Part of Planned Renovation

While the decision of the homeowner to retrofit may be influenced by improved comfort and reduced fuel consumption, the major legitimizing factor for whole house retrofit work is as part of ongoing or planned renovation activities around the house. It can be difficult to justify the entire cost of the total retrofit strategy solely on a financial basis, especially where the cost of a retrofit includes non-energy related expenses such as cladding, interior finishing, re-roofing, painting, etc.

When the retrofit work is "piggybacked" onto planned renovation activities, however, the only factors which need to be assessed are the incremental costs associated with the energy upgrading. Paying \$40 to \$50/m^2 for a wall retrofit would prove a poor investment in terms of energy savings. But, if the homeowner has already committed \$30/m^2 for new drywall, the economic picture is significantly improved.

Not considering the potential for thermal upgrading as part of ongoing renovation activities is a waste of an excellent opportunity by the homeowner.

Chapter 3 of the manual presents different criteria for assessing the existing condition of the house and the requirements of the homeowner in light of the potential retrofit activities.

1.3 DIFFERENT LEVELS OF RETROFIT

The specific approach to retrofitting will be influenced by the condition of the house and the interest of the homeowners. Depending on the situation, the house and homeowner may demand less than a total retrofit. Retrofit work can be categorized into three different stages, or approaches, i.e., low level retrofit work; medium level retrofit work; and whole house retrofit work.

The different retrofit approaches are distinguished by the amount of investment required by the homeowner and the level of work required on the house.

Low Level Retrofit work generally consists of plugging obvious leaks around the house: air leaks, missing insulation and poorly operating mechanical equipment. Generally, this level of activity falls within the scope of air sealing contractors, blown-in insulation contractors, furnace maintenance contractors and energy advisory firms. Most of the work which falls into this category can be performed with only minor inconvenience to the homeowner and requires an expenditure of, at the most, several hundred dollars.

A low level retrofit approach is usually chosen because of a limited budget or the relative newness of the house.

Medium Level Retrofit work generally consists of reinsulation work of a more significant nature, for example: upgrading the insulation levels of the house foundation or above grade walls, or installing new windows. This level of retrofit work will demand a more significant capital outlay and can result in a greater disruption of the house occupants. Most retrofit strategies falling into this category are influenced by the renovation activities required around the home.

A **Whole House Retrofit** may employ many of the techniques used in both low level and medium level retrofit work. The total retrofit goes further than this, in that it involves all the components of the envelope as well as the mechanical and ventilation systems.

The total retrofit requires a unified approach to the existing house and deals with the house as a system. This highlights the close interrelationship between attic, wall and basement reinsulation, air tightness, the need for mechanical ventilation, the implications of a significantly reduced heating demand, and the requirements for combustion air.

No two houses will ever meet the same requirements for retrofit, and no two houses need to use, or will adapt to, the same techniques. The majority of this manual describes the many different techniques and approaches which can be used with whole house retrofit work.

1.4 WHICH HOMES ARE RETROFIT CANDIDATES?

Houses come in many shapes, styles and conditions. It is important to realize that not all houses are appropriate for energy conservation retrofits. Even if the homeowner is committed to energy conservation work, it may not be wise to invest heavily in the retrofit where the proposed work would outlast the structure of the house. Some houses are good candidates for major exterior retrofit work, and some houses are logical candidates for interior retrofit work. And some buildings are best suited to the wrecker's ball.

Newer houses in good aesthetic and structural condition don't often present a major opportunity for total retrofit work. If the house interior is well appointed and the exterior is not in need of work, the best advice would be to pursue low-level retrofit activities such as air sealing and upgrading attic or basement insulation.

The best candidate for a total retrofit is the house which is undergoing major renovation work. Where the house interior is being 'gutted', or where major exterior work (re-siding, etc.) is being planned, whole house retrofit techniques can be most easily justified.

1.5 IMPLICATIONS OF A TOTAL RETROFIT

The application and installation of whole house retrofit techniques on an existing house will have a major effect on the way the house looks, feels and performs. In fact, most changes will be for the better: improved comfort, lower operating costs, etc. If not well planned, however, the whole house retrofit can provide unwelcome surprises, such as the need for a mechanical ventilation system and an altered heating system.

When problems arise from retrofit work, it usually means that a 'total' approach to the job has not been followed. For example, problems relating to poor air quality and lack of adequate combustion air mean that an adequate mechanical ventilation strategy was not followed. Where the house heating system is not performing adequately, the interrelationship between the envelope and the distribution systems has not been properly understood.

Chapter 11 of the manual discusses the effects of the improved building shell on house mechanical systems. While not an exhaustive treatment of the topic, the builder will be provided with guidelines to ensure the safe operation of the house ventilation and heating systems.

2

HEAT, AIR AND MOISTURE FLOWS IN HOUSING

A whole house retrofit project will usually involve integrating energy conservation measures with other renovation work. Perhaps more importantly, the successful retrofit will recognize that the modern home is a complex system. Changes to the envelope, for example, will not only affect the heating requirements but may also affect air quality, ventilation and durability of the structure. Chapters 5 through 9 of this manual provide many examples of strategies and techniques suitable for this type of work.

Houses rarely match textbook examples. The nature of renovation work requires that the contractor assess each home on an individual basis and devise a customized plan that will suit several requirements:

- the needs and desires of the homeowner;
- the age and general condition of the house;
- how the house was constructed;
- local climate conditions; and
- local availability of specialized materials.

This chapter will outline the building science principles relating to heat loss and moisture movement and illustrate how these principles are applied in retrofit work. With a thorough understanding of the principles behind retrofit strategies, the contractor will be able to select or adapt techniques to suit particular site conditions.

2.1 HOUSES AND ENERGY

Energy, in all its forms, represents the capacity to do work; heat is simply the lowest form of energy. Energy is used in the home for a number of purposes but, for the average household, space heating is the single largest energy requirement.

Whenever there is a temperature difference, heat moves from hot to cold. Thus, during the winter months, heat is continually leaving the house. In order to maintain a constant comfortable temperature in the home, sufficient heat must be supplied in order to match the losses.

Heat Losses

Heat losses from the home occur through three mechanisms: transmission losses, air exchange and combustion losses (Figure 2.1).

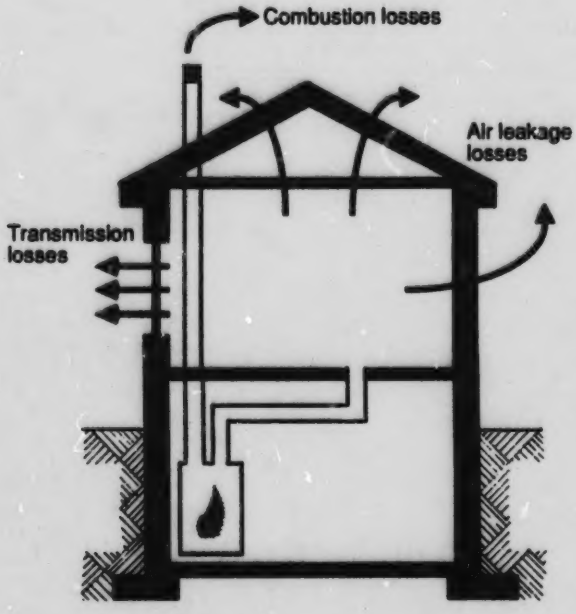


Fig. 2.1 Heat losses

Transmission losses (conductive and radiant) are heat losses through the house envelope. The relative proportion of losses through various sections such as the above-grade walls, ceiling, basement, doors, and windows will depend on the design of the home.

Air exchange due to ventilation and air leakage represent losses of heated house air through the envelope. This can account for a significant proportion of house heat losses, usually from a quarter to a third of the total.

Combustion losses are incurred with furnaces which use heated house air to support combustion and to maintain a positive draft in the chimney, and which eventually exhaust the warm air to the exterior.

Heat Sources

Heat sources within the home include the following: (Figure 2.2).

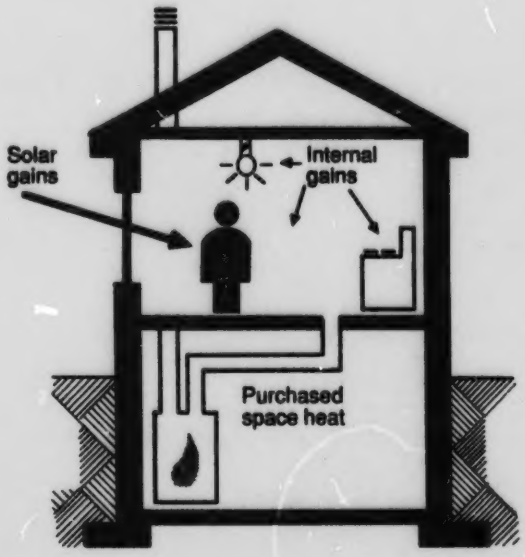


Fig. 2.2 Heat sources

Purchased Space Heat - Space heat is purchased in order to maintain a comfortable indoor temperature when internal and solar gains do not equal the house losses.

Internal Gains - Useful heat is generated from lights, appliances, and hot water heating as a by-product of their main function. Internal heat gains are also supplied to the home by the occupants themselves.

Solar Gains - Solar energy can contribute substantial amounts of intermittent heat to the home, depending on the size, design, and orientation of the windows. Chapter 9 of the manual presents some guidelines respecting design for solar energy.

A whole house retrofit will radically change the house energy balance sheet. Heat losses can be reduced by 50% to 90%, which will obviously reduce the requirements for purchased space heating.

2.2 HEAT AND HOW IT MOVES

Heat is a form of energy associated with the movement of molecules; cold is simply the absence of heat. Heat moves because of a temperature difference and it always flows from hot to cold.

Heat travels by three principal means: conduction, convection and radiation. The rate of heat transfer depends on the amount of temperature difference between the hot and cold area, and the resistance to heat transfer of any materials in the path of the heat flow. For discussion purposes the three heat transfer mechanisms will be discussed individually, but in a complex assembly such as a house all three act simultaneously (Figure 2.3).

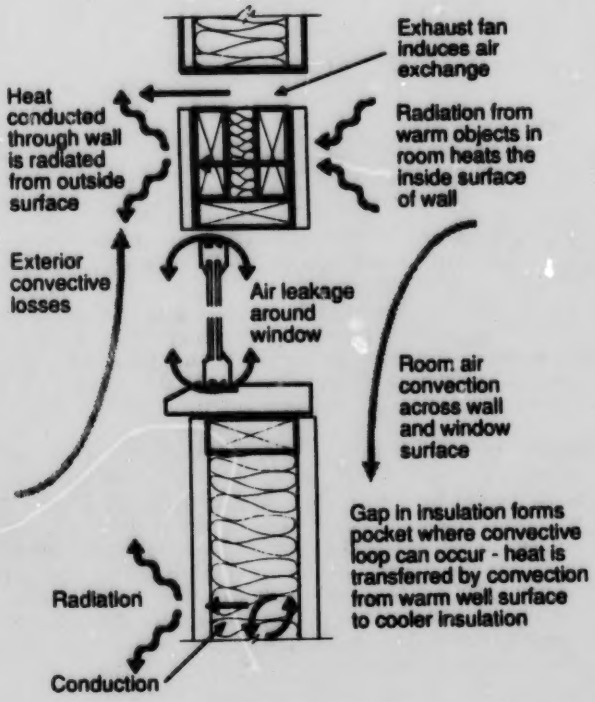

Exhaust fan induces air exchange
Heat conducted through wall is radiated from outside surface
Radiation from warm objects in room heats the inside surface of wall
Exterior convective losses
Air leakage around window
Room air convection across wall and window surface
Gap in insulation forms pocket where convective loop can occur - heat is transferred by convection from warm wall surface to cooler insulation
Radiation
Conduction

Fig. 2.3 Types of heat movement

Conduction is the only means by which heat is transferred through a solid material. It is the result of molecular activity within the material and occurs when one area is warmer than another. Molecular activity (heat) is transfered to less active molecules. Conduction will continue until the temperature is equalized throughout the material.

Convection refers to heat transfer which occurs when a fluid (liquid or gas) flows over a surface which is either warmer or cooler than the fluid. As a case in point, when cool air passes over a heated surface, heat flows to the air and is carried away. When the warmed air comes into contact with a cooler surface, the flow of heat is reversed. Convective movements can be caused by temperature and/or pressure differences, or by mechanical action such as a fan.

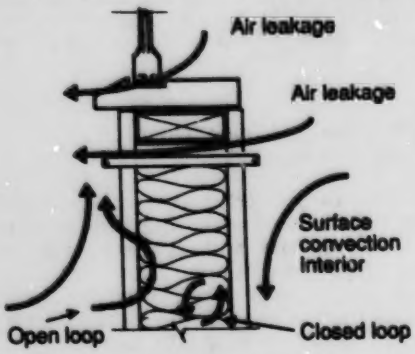


Fig. 2.4 Types of air movement

The major convective heat losses in the home are illustrated in Figure 2.4:

- air movement over the surface of the envelope; and
- open or closed convective loops inside the insulated walls.

Radiation is unique. It is the only form of heat transfer that does not require an intermediate material. Radiation can travel equally well through air or a vacuum. In terms of energy losses, the effects of radiation are seldom considered alone, but in combination with the other mechanisms of conduction and convection.

Radiant energy from the sun can contribute substantial heat gains to the home. Practical applications of radiation theory relating to housing have concentrated on improving window performance to maximize solar heat gains during the winter and minimize the summer cooling load. These strategies are discussed in Chapter 9.

In building practice, heat transfer through the house envelope is considered under two general headings:

- **transmission losses**, which refer to the combined effects of conduction, radiation and convection within the building assembly; and
- **air exchange**, which is used to describe the effects of ventilation and air leakage.

2.3 TRANSMISSION LOSSES

Heat transfer by conduction provides the basis for analyzing transmission losses through individual materials or through building assemblies. The contractor can evaluate the performance of various envelope designs and predict the size of the heating system required after the retrofit. As discussed in Chapter 5, design heat loss will also include losses associated with air exchange. This evaluation can be performed either manually or by computer simulation.

2.3.1 How Heat Moves Through the Envelope

As discussed earlier, conduction is influenced by a difference in temperature – with heat always moving from hot to cold. The calculations used in analyzing conductive heat loss assume that heat flow always occurs in one direction and that the temperature drop across the envelope is constant. While heat flow is actually multi-directional, the standard calculation procedure provides acceptable results by assuming the flow is linear.

2.3.2 Calculating Conductive Heat Losses

The characteristics of conductive heat transfer are the building blocks of the heat loss equation shown below.

$$\text{amount of heat transferred} = \frac{\text{area} \times \text{temperature difference}}{\text{resistance value}}$$

This equation is expressed as:

$$Q = \frac{A \times \Delta T}{R} \quad \text{or} \quad Q = U \times A \times \Delta T$$

where:

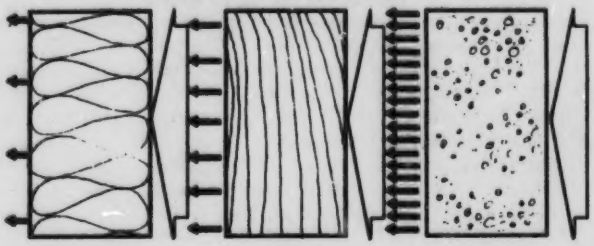
Q is the rate of heat transfer through a specific area of the material or assembly being studied. Q is expressed in watts or joules/second.

R is the resistance of the material or assembly to conductive heat transfer. A material's resistance is the reciprocal of its conductivity: R = 1/U. Poor conductors are good insulators; the higher the R value the better the material is at resisting heat transfer by conduction. The R value of a given material in use will depend on its applied thickness. R values for common building materials are expressed per mm or for a given thickness for unit materials such as concrete blocks. The charts in Appendix A can be used to identify the R value of most building materials (Figure 2.5). Units of resistance are expressed in RSI units ($°Cm^2$/watt).

To calculate the total RSI value for a given building assembly, the RSI values for the specified thicknesses of the materials are calculated separately and then totalled. To this is added the RSI value for the air film that clings to the inside and outside surface of the wall.

U represents the material's conductivity, its ability to transfer heat by conduction. The U value of a material represents the rate of heat transfer in watts or joules/s through 1 mm of the material at a temperature difference of 1 °C. U is expressed in watt/ $°Cm^2$.

Heat transfer by conduction



	Glass Fiber batt	Wood	Concrete (1760 kg/m³)
RSI	3.5	1.2	0.2
U	0.29	.82	5.49

Fig. 2.5 Relative values of RSI and U for different materials, 140 mm section

ΔT is the difference in temperature from one side of an assembly to the other, usually room temperature minus the outside temperature. The greater the temperature difference, the greater the rate of conduction. ΔT is expressed in °C.

When the rate of heat transfer through the envelope must be determined in order to size heating equipment, the ΔT used is usually the "design temperature". This ΔT is the difference between the indoor and the outdoor temperature for the coldest day of the year to be expected. The design temperature will only be exceeded 1% or 2 1/2 % of the time. Calculating heat loss at the design temperature will estimate the maximum rate of heat loss from the house.

A is the area of the material or assembly being studied, expressed in square metres. In designing a building envelope, emphasis is placed on reducing heat loss through those sections with the largest area.

While comparatively low R values for small sections of the envelope may be acceptable from the point of view of overall heat loss, care should be taken with details such as bay window projections or header joists to provide sufficient insulation to avoid cold surfaces and possible condensation problems.

Using the heat loss equation as shown, the performance of various designs may be evaluated for any specified area of the envelope. Chapter 5 shows

house design heat losses in order to size heating equipment, and how to calculate annual fuel consumption in order to estimate energy savings through retrofit measures.

2.3.3 *Minimizing Conductive Heat Losses in Design*

Using heat loss calculations (and experience), the contractor will be able to understand the importance of good design strategies. A good retrofit design will maximize insulation levels while minimizing the use of framing materials which can act as thermal bridges.

Thermal Bridges A thermal bridge is a weak point in an envelope assembly where heat is easily transferred by conduction across the "bridge". For example, in a typical wall section using 38 x 89 mm studs, it can be seen that the R value through a section at the stud (Figure 2.6a) is considerably less than through the insulated portion of the wall (Figure 2.6b). This difference is significant since studs can account for 20% of the total wall area. Careful framing techniques and the use of insulated sheathing can minimize the effect of thermal bridging through the wall assembly.

Resistance through a wall	RSI
Inside air film	0.12
Drywall, 13 mm	0.08
Glass fibre batt, 89 mm	1.80
Extended polystyrene, 38 mm	1.33
Lap siding	0.14
Exterior air film	0.03
Total RSI	3.50
U value (1/RSI)	0.29

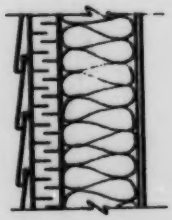


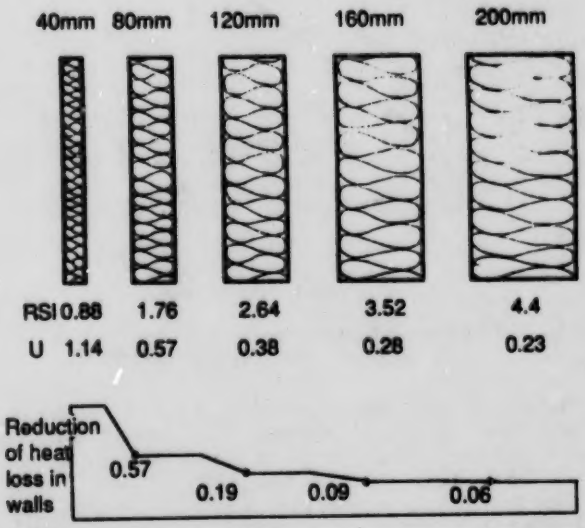
Fig. 2.6 (a)

Resistance through studs of a wall	
Inside air film	0.12
Drywall, 13 mm	0.08
Stud, 89 mm	0.77
Extended polystyrene, 38 mm	1.33
Siding	0.14
Exterior air film	0.03
Total RSI	2.47
U value (1/RSI)	0.40

Fig. 2.6 (b)

Optimum Insulation Levels It is theoretically possible to reduce conductive heat losses through the building envelope to negligible rates. But this is not a practical approach. While each additional thickness of insulation costs the same as the layer before it, the potential energy savings are a little less (Figure 2.7). In practical terms the optimum amount of insulation is determined by several factors:

- the physical constraints of the building — available space for insulation in the wall or roof assembly;
- the local climate — the more severe the climate the greater the potential savings from additional insulation;
- the projected installed cost of the insulation;
- accessibility and ease of adding additional insulation at a later date, for example, attics compared to walls; and
- local fuel prices and projected fuel costs.



Note:
Example uses RSI value for glass fibre batt type insulation 40 mm = RSI 0.88

Fig. 2.7 Effect of incremental amounts of insulation

2.3.4 *Maximizing Effectiveness of Insulation*

Still air is an excellent insulator and insulation materials are designed to resist the flow of heat by trapping still air in various ways. As an example, it is not the glass fibres in fibreglass insulation which restrict heat flow. In fact, the glass fibres are extremely good conductors. The benefit of the glass fibres is their ability to encase still air. Maintaining the effective R value of any insulation material depends on proper design detailing and installation — ensuring that the still air cavities are maintained.

Insulation materials must be **uniformly applied** in order to trap still air and work effectively. Improperly filled stud spaces, gaps or folds in the material, or insufficient material around projections, such as pipes, can permit the formation of convective loops, reducing the overall R value of the section by as much as 10% to 20%. The compression of insulation materials should also be avoided. Depending on the amount of compression, the effective resistance (per installed mm) can be reduced by as much as 30% (Figure 2.8).

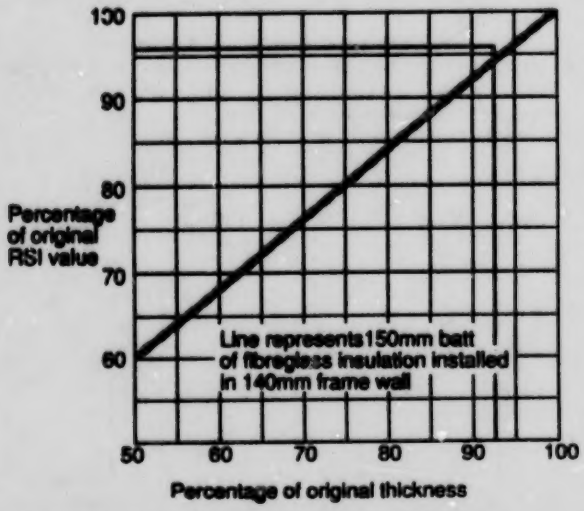


Fig. 2.8 Effect of compressing batt-type insulation on its thermal resistance

Insulation materials must be installed with an **adequate weather barrier** – protecting the material from wind-driven air which can blow into the wall. This disturbs the still air spaces and effectively reduces R values by decreasing the temperature within the insulated section (Figure 2.9).

Some insulation materials must also be protected from moisture as dampness in the material can cause compression. Saturated materials are poor insulators since air is replaced by water which more readily conducts heat. Moisture protection must be provided both in the form of a weather barrier to protect against wind-driven rain, and in the form of an air barrier and vapour barrier to protect against moisture originating in the home.

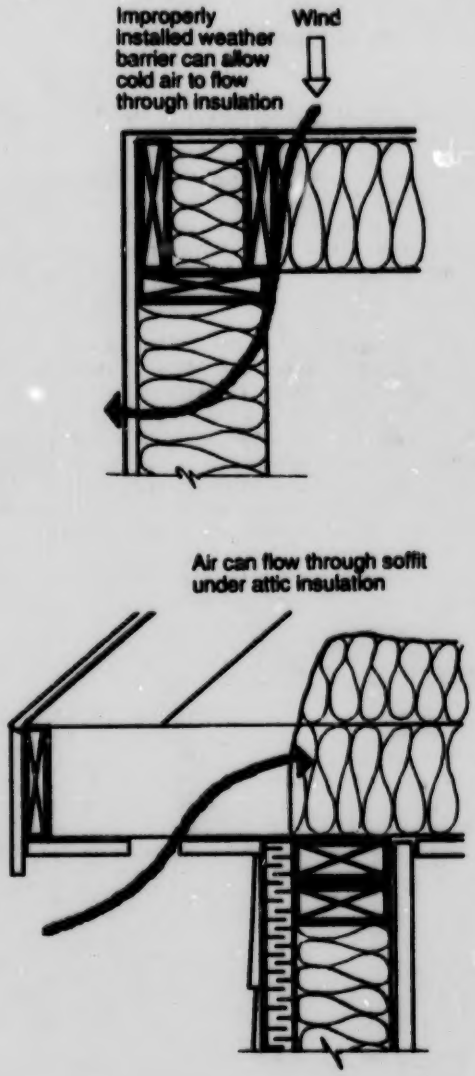

Improperly installed weather barrier can allow cold air to flow through insulation
Wind
Air can flow through soffit under attic insulation

Fig. 2.9 Potential weak points

An effective retrofit will:

- concentrate on adding high levels of insulation to building sections with the largest area and to those sections where it will be difficult to add more material at a later date;
- minimize thermal bridging in the design and installation of framing and sheathing;
- maximize the effective R value of insulation materials by careful installation, avoiding gaps where convective loops could form;
- provide a weather barrier to protect the insulation from wind and rain; and
- provide an air barrier and vapour barrier to protect the insulation from moisture-laden air originating in the home.

2.4 AIR EXCHANGE AND HEAT LOSS

The exchange of air between the house interior and the outdoors can be described in two categories. Controlled air exchange used to provide ventilation will vary depending on the operation of windows, exhaust fans, dryer vents, etc. Uncontrolled air exchange or air leakage results from infiltration and exfiltration through cracks and holes in the house envelope. In houses built before 1976, air exchange can represent 20% to 50% of the house heat loss.

Air leakage rates can be measured using a variety of testing techniques. The results can be expressed in air changes per hour (ACH) and are used to estimate the overall contribution of air leakage to house heat loss. Typical natural air change rates of houses built before 1976 range from 0.3 to 0.7 ACH. In other words, in each hour, a volume of air equivalent to 30% to 70% of the house volume will be replaced by outside air. The air change rate of newer houses will be lower, while very old houses may experience air change rates greater than 1 ACH.

2.4.1 Calculating Air Leakage Loss

The equation below is used to calculate hourly design heat losses due to air leakage:

$Q = 0.361 \times V \times \Delta T \times ACH$, where:

Q is the rate of heat transfer due to air leakage for the house being studied, as expressed in Watts or Joules/second.

0.361 is a constant value combining the density and heat capacity of air. This reflects the amount of heat carried in each m^3 of air.

V is the total volume of the heated areas of the house as expressed in m^3.

ΔT is the difference between indoor temperature and the design temperature as expressed in °C.

ACH is the number of natural (not ventilation fans) air changes per hour through the house envelope as estimated based on an air leakage test or educated guess.

2.4.2 Factors Affecting Air Leakage

Two conditions are required for air leakage to occur:

- penetrations in the envelope (discussed in Section 2.4.3); and
- a pressure difference across the hole.

Three factors contribute to the pressure difference between inside and outside during the winter conditions: stack effect, exhaust effect and wind effect.

Stack effect - Since indoor air is warmer than outdoor air, it is less dense and tends to rise due to buoyancy. This creates a negative pressure on the lower levels of the house, encouraging infiltration. At the upper levels, air exfiltrates through openings and heat and moisture are lost to the outdoors (Figure 2.10).

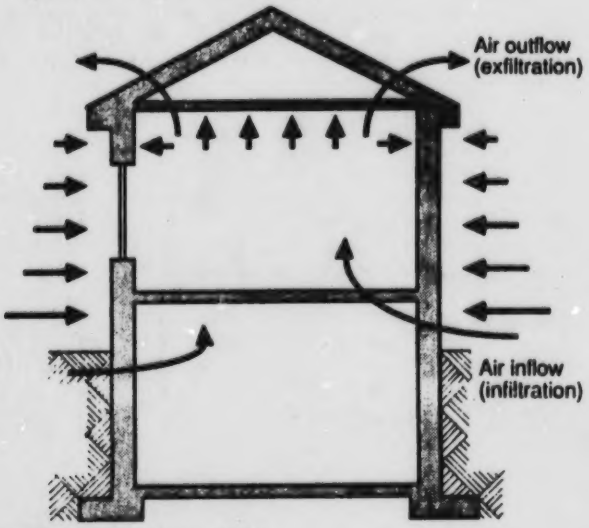


Fig. 2.10 Stack effect

Exhaust effect - Appliances such as stoves, fireplaces, furnaces, and water heaters require air for combustion and to promote flue draft control. Similarly, kitchen and bathroom fans and clothes dryers can be exhausting large quantities of air. The exhaust air carries with it large quantities of heat and water vapour. These large air requirements can often create a negative pressure throughout the whole house, encouraging infiltration at every level (Figure 2.11).

Wind effect - Wind is another variable affecting day to day changes in the air leakage characteristics of a house. Strong winds can cause a positive pressure on the exterior windward side, driving air into the building, while the resulting negative pressure on the leeward side promotes exfiltration and losses of heat and water vapour (Figure 2.12).

2.4.3 Typical Locations of Air Leakage

Building diagnostic techniques have been developed which make it possible to determine exactly where air leakage occurs through the envelope. As illustrated in Figure 2.13, typical locations include:

- structural joints in the building, at floor headers, the top of partition walls and the junction of the foundation wall with framing, and where partitions meet exterior walls;
- electrical outlets on exterior walls;
- around kitchen and bathroom exhaust vents;
- around electrical and plumbing chases which penetrate exterior walls and the attic;
- around chimneys – at the junction with the house wall and at attic penetrations;

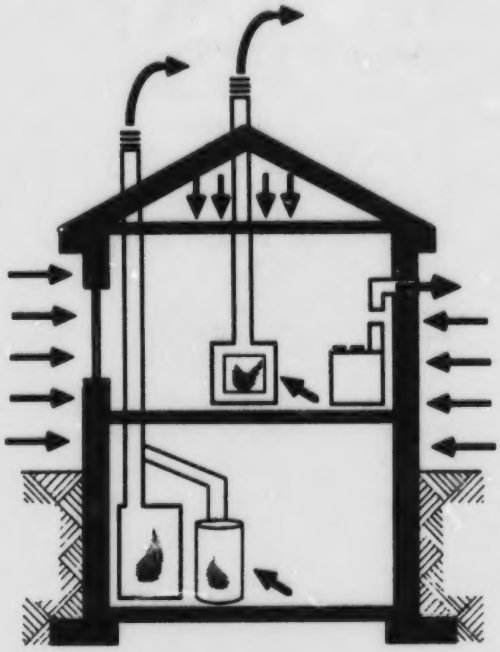


Fig. 2.11 Effect of combustion appliances

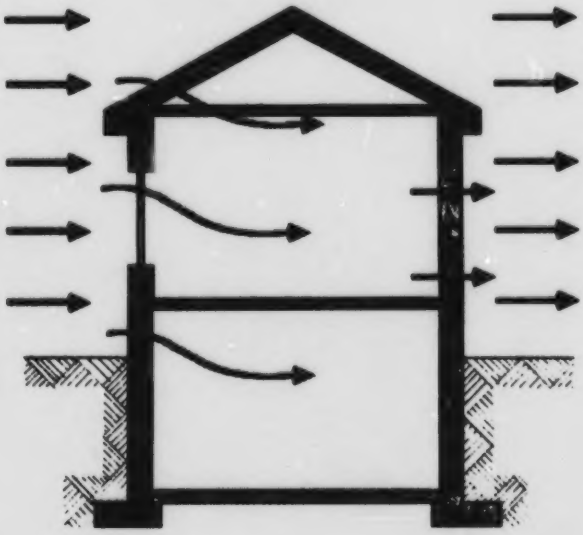


Fig. 2.12 Wind effect

- windows and doors, as well as the attic hatch; and
- basements, through cracks in foundation wall and floor drains as well as through utility penetrations and the structural joints mentioned above.

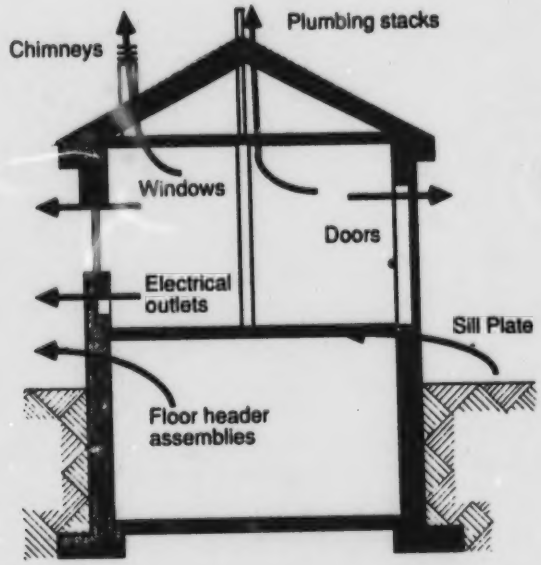


Fig. 2.13 Typical air leakage locations

2.4.4 Strategies to Reduce Air Leakage

A total retrofit project includes a complete air tightening of the house envelope, even where additional insulation is not being provided. This is because of the relative importance of air leakage to house heat loss and because of the effect of air leakage on moisture transport (which will be discussed in Section 2.5).

Improving the air tightness of the house envelope is accomplished by providing a continuous air barrier. Whole house air tightening involves a variety of materials and techniques, including:

- **sheet or rigid materials** that restrict the passage of air which are used for large expanses of the envelope such as walls and ceilings;
- **caulking, tape and gaskets** that seal joints in the main air barrier and penetrations through it; at openings in the envelope the main air barrier material is sealed to the door or window frame; and
- **weatherstripping** that provides a seal at moveable joints such as door and window openings.

The type of materials used and how they are applied will vary, depending on:

- whether the air tightening is being done alone or as part of reinsulation work;
- whether the insulation is added as part of an interior or exterior retrofit;
- the age and condition of the home and the method of its construction; and
- the particular design chosen for the retrofit work.

Air barrier strategies appropriate for various circumstances are discussed in Chapters 6 to 10. All strategies follow the basic principle that **the air barrier must be continuous.**

In many applications one material is used to provide both a continuous air barrier and a vapour barrier. When materials are used in the dual role of air barrier and vapour barrier they **must be located on the warm side of the assembly.**

An effective retrofit will:

- substantially reduce air leakage losses by providing a continuous air barrier on new work;
- provide air tightening on any other components of the envelope which are not part of the total retrofit work; and
- ensure that the air barrier, when combined with a vapour barrier, is installed on the warm side of the building envelope.

2.5 MOISTURE FLOWS

Moisture damage is the major cause of building material failure. Protecting the building structure from moisture damage has been an on-going concern in building technology.

A retrofit project presents the opportunity to diagnose and remedy existing problems. An understanding of moisture flows will enable the contractor to design protection for both the existing assembly and the newly added materials.

Problem-causing moisture can originate from external sources such as precipitation, groundwater, and ice damming or it can be generated internally by the occupants or stored by the building. Traditional building practice has developed effective strategies for protecting the envelope from externally generated moisture. With recent changes in building technology, particularly the addition of increasing amounts of insulation to the envelope, an understanding has developed of the role of internally generated moisture.

2.5.1 Internally Generated Moisture

Under normal conditions, a considerable amount of water in the form of water vapour is generated within the home by the occupants and the building itself. Building materials such as wood experience a yearly moisture cycle, absorbing moisture in the spring and summer when outdoor humidities are high and releasing it in the fall and winter when humidity levels start to fall. Occupants generate significant amounts of water through activities such as cooking, bathing, floor washing and laundry, through operation of humidifiers and through physical activity.

2.5.2 Transport of Water Vapour

Water vapour can be transported in two ways: by diffusion and by the movement of air .

Diffusion is the movement of water vapour through a material caused by the difference in vapour pressure from one side of the material to the other. A material's ability to allow the diffusion of water vapour is known as permeance. The lower the permeance, the greater the ability of the material to resist diffusion. Permeance ratings for common building materials are provided in Appendix B.

It was first thought that **diffusion** was the main mechanism for the transport of water vapour through the building envelope. As a preventative measure, most houses built after 1940 were provided with a vapour barrier – a material of low permeance installed next to the interior wall finish (Figure 2.14). This was often paper-backed insulation and, more recently, polyethylene. Since the amount of water vapour transported by diffusion is directly related to area, the vapour barrier was considered adequate if it covered most of the section. There was no attempt to make it continuous throughout the envelope.

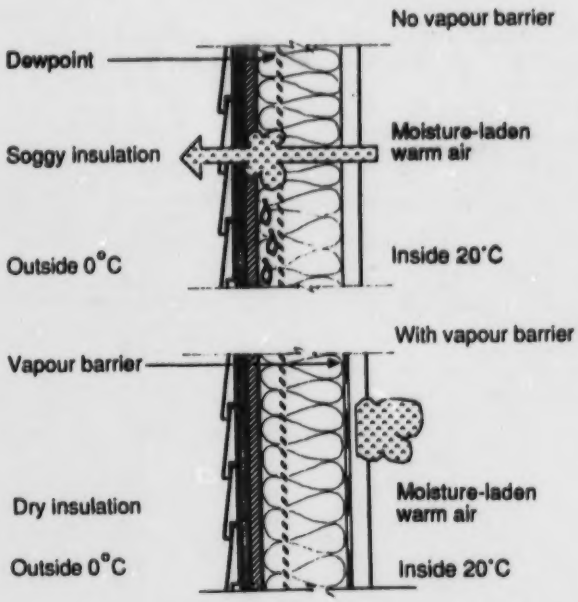


Fig. 2.14 Movement of vapour through a wall

More recently it has been documented that **air movement** accounts for far greater amounts of water vapour transport than diffusion. Figure 2.15 shows the relative amounts of water transported by diffusion and by air leakage over a typical heating season. As the chart demonstrates, water vapour diffusion is a slow process and is a secondary transport mechanism when compared to air leakage.

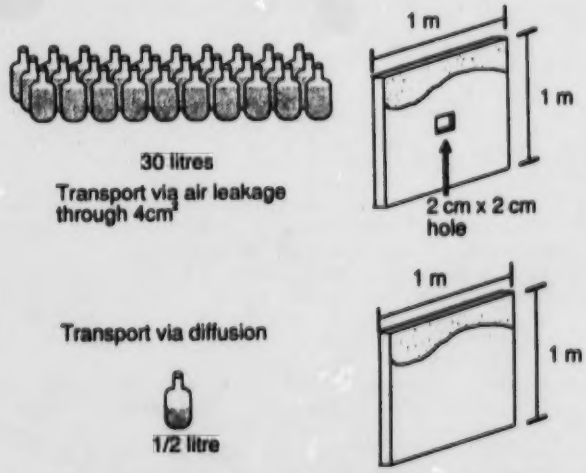


Fig. 2.15 Moisture transport over one heating season

2.5.3 Condensation

Water vapour in itself is not a threat to building materials. However, in vapour form, water can be transported easily to locations in the envelope assembly where it can condense to liquid water and lead to rot, decay and corrosion of adjacent materials. Warm air can hold a greater amount of water vapour than cool air. Condensation occurs when air is cooled to the "dew point" where it releases some of the water vapour as liquid on nearby surfaces. In extremely cold conditions, the water can be deposited as frost. Condensation as water or frost can be readily seen when warm room air is cooled when it contacts a cold surface such as a window.

To protect the building assembly, water vapour must be prevented from reaching a surface that is below dew point temperature, the temperature at which it will condense as liquid water or frost.

2.5.4 Role of Air Barrier and Vapour Barrier

The various designs for whole house retrofit work described later in this manual present the need for both a vapour barrier and a continuous air barrier in the envelope assembly. While these systems may vary in the choice of materials and location of the vapour barrier and air barrier, they all follow some basic application principles.

1) The vapour barrier should be on the warm side of the insulation to prevent water vapour originating in the house from reaching the dew point temperature and condensing in the wall. Traditional practice places the vapour barrier just beneath the interior wall finish but research has shown that it can be located within the wall assembly provided that two-thirds of the RSI value of the wall is on the cold outside of the vapour barrier (Figure 2.16). This general rule of thumb relates to most areas of the country. In the far north, a safer rule would be that three-quarters of the insulation is on the outside of the vapour barrier. The advantage of 'burying' the vapour barrier in the wall assembly is that deliberate penetrations for plumbing and wiring, and accidental damage during the construction process will be minimized.

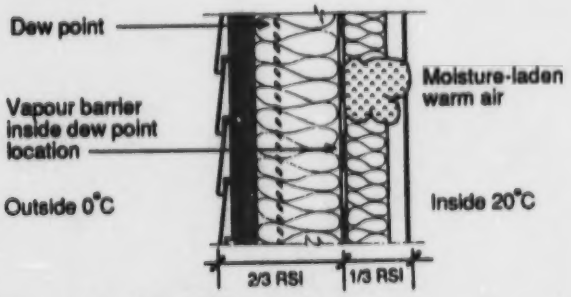


Fig. 2.16 Recessed vapour barrier

2) The continuous air barrier, when installed as a combined air barrier and vapour barrier, must meet the location requirements of the vapour barrier described above. Even where separate materials are used for these functions, the air barrier is generally installed on the warm side of the wall.

3) Any water vapour that does penetrate the wall assembly should be permitted to exit to the outside. Building materials used as vapour barriers can slow the rate of diffusion but they cannot stop it completely. Any moisture that does pass through or around the vapour barrier should be allowed to exit freely to the outside of the wall. This is done in two ways:

- by specifying outer wall materials that are more permeable than the vapour barrier, i.e., materials with higher permeance ratings – a rule of thumb suggests that the outer surface be 10 times more permeable than the interior surfaces; and
- by leaving seams of low permeance materials unsealed.

2.5.5 Externally Generated Moisture

Outdoor moisture which can affect the building envelope originates from precipitation (rain and snow), from run-off and from groundwater present in the soil.

2.5.5.1 Moisture Transport Above Grade

Rain and snow can enter the wall through openings in above grade sections of the envelope. Once the exterior cladding has been wetted, less obvious mechanisms such as pressure differences and capillary action can drive the moisture deeper into the wall assembly.

Pressure differences through the wall are caused by wind and/or vapour pressure. If there are openings in the wall, the pressure difference can cause substantial amounts of water to be forced into the openings.

Capillary action enables water to cling to a material by means of surface tension. If the material is porous enough, water will eventually penetrate.

Traditional building practice has developed a number of effective strategies to protect the building structure from water damage. These are based on the common principle of providing two or more layers of protective material which shed the water out and away from the envelope.

- The covering of the building envelope incorporates a three-part protection system consisting of:

  1. roofing or cladding materials, which are the primary defence;
  2. a water repellant weather barrier that protects the insulation and framing from any water that does penetrate the outer cladding; and

3. flashing, gutters and overhangs which direct any run-off out and away from the building.

- Additional flashing is used at penetrations in the envelope such as window head and sills, and chimneys.

More recently a variation of this approach for walls, called the "rain screen", has been developed. By providing an air space behind the primary covering and by venting this air space to the outside, pressure is equalized across the cladding and water penetration due to pressure difference is substantially reduced. The weather barrier under the cladding, in addition to being water repellant, must be able to withstand windloading.

2.5.5.2 *Moisture Transfer Below Grade*

The movement of water below grade is largely dependent on the type of soil around the foundation, the height of the local water table and the type of foundation.

Poorly finished grading around the house can promote the accumulation of run-off near the foundation wall. Water will readily penetrate granular backfill and can be directed to a perimeter drainage system which will carry it away from the foundation. On the other hand, fine grained soils such as silt or clay will absorb large amounts of moisture and maintain damp conditions adjacent to the foundation wall.

Where a large amount of water is present in the soil, water pressure can force the liquid through cracks in the foundation wall and at the junction between the floor slab and wall.

Where the soil around the foundation is damp for extended periods, capillary action can result in the continual transport of water through porous foundation materials. This moisture eventually escapes by evaporation from exterior above grade portions of the wall or from the interior foundation surfaces. Continual moisture transport through the foundation can

- add to the water vapour present in the home, raising the humidity to unacceptable levels;
- damage interior finishes below grade;
- lead to unsightly efflorescence on above grade foundation walls; and
- cause deterioration through freeze-thaw cycling.

Where water penetrates the foundation, an exterior retrofit is recommended. This will permit the installation of a new drainage system, granular backfill and new grading away from the house.
A dampproofing or waterproofing course, generally of bituminous material, will serve as the final protection for the wall from water penetration. It will also protect the insulation from moisture in the wall. In addition, with exterior retrofit it is possible to install free-draining rigid insulation which will direct water to the perimeter drainage system (Figure 2.17).

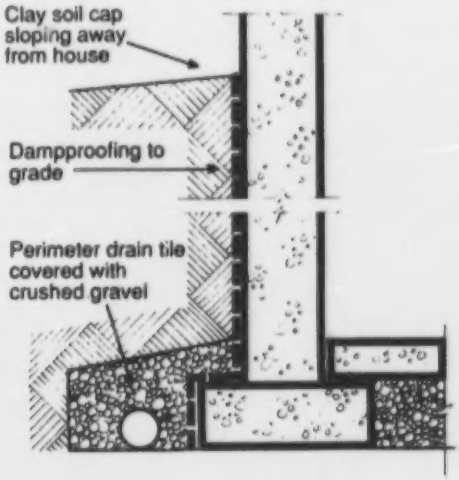


Fig. 2.17 Proper drainage procedures

An interior retrofit is feasible for foundations which experience moisture but not actual water penetration. An essential step with interior retrofit is the installation of dampproofing against the existing foundation wall (Figure 2.18). This material protects the framing and insulation from the effects of moisture in the wall. Details for dampproofing will vary with the type of foundation and are presented in Chapter 7.

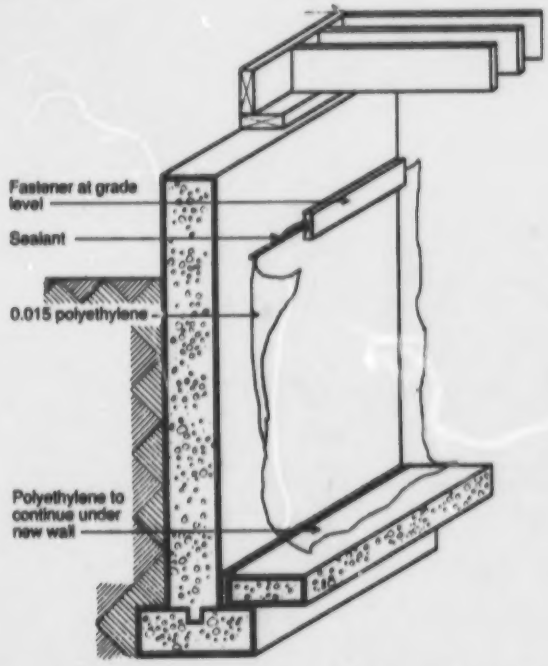


Fig. 2.18 Interior dampproofing of foundation walls

3

ASSESSING THE HOMEOWNER AND THE HOUSE

A successful retrofit is determined by such factors as the ability of the contractor to assess the specific house and the requirements of the homeowners. No single retrofit strategy can be developed in isolation from the homeowner's budget, needs and aesthetic desires, and any retrofit strategy must be developed to ensure technical compatibility with the house being considered.

Determining the most suitable strategy for the specific house and homeowner requires a great variety of skills. The contractor must have a sound knowledge of the different retrofit options. The assessment of the condition of the house may call upon the contractor's knowledge of engineering issues. The finished design should demonstrate an architectural talent for integrating the new with the old. And finally, bringing in the proposed design on budget requires the skills of a sound financial manager and possibly the talents of a banker.

This manual is not intended as a training manual on how to become a successful general contractor. Issues relating to engineering, architecture, and financing will require further research. This manual does present the various factors influencing the design of whole house retrofit work.

This brief chapter will provide an overview of the issues involved in cost/benefit assessment. While it is possible to perform most of this work using manual calculations, the recent availability of computer programs in this field should satisfy those individuals seeking background information about heat loss analysis and potential dollar savings. Whether the analysis is to be performed manually or by computer, the results of the calculations will only be as good as the accuracy of the data employed.

To assist the contractor in seeing the potential costs and savings resulting from the total retrofit, several case studies will be presented in the Appendix at the end of the manual. These examples suggest the wide range of techniques which can be used to attain major energy savings. The examples suggest the difficulty in accounting for what specifically are energy-related costs versus renovation costs – a complicated issue when major renovations are being performed.

This chapter offers basic advice for contractors on how to market their newly-found expertise in the field of energy-efficient retrofit work. All the skills and knowledge in the world are wasted unless they are actually being employed.

3.1 ASSESSING THE HOMEOWNER'S NEEDS

The homeowner pays the piper. It matters little that the contractor is sold on advanced retrofit work, or that the cost of any such work can be justified in economic or structural terms. If the homeowner doesn't want or cannot justify retrofit-related activities, the contractor may be barking up the wrong tree.

The role of the successful contractor is to integrate the homeowner's stated needs and requirements with the condition of the house and the budgetary restrictions of the homeowner. The contractor must show the homeowner how the retrofit techniques can be integrated into the renovation to the homeowner's benefit.

3.1.1 The Renovation Process

A contractor is generally called in by a homeowner to offer suggestions and/or quotes on a specific piece of work. It is seldom that the homeowner is only looking to reduce the house fuel requirements. The contractor is usually requested to respond to one of several requirements of the homeowner:

- the building requires immediate upgrading caused by a leaky basement, shifted structure, etc.;
- the building requires alterations to improve the appearance or performance, i.e., recladding, repainting, etc.; and
- the building requires renovations to make the house better suited to the homeowner's requirements: upgrading basements and attics into living areas, altering the house floor plan, adding space to the house, or general modernizing.

The contractor should be able to assess the homeowner's needs and determine which renovation activities allow piggybacking of energy-related work. The following charts identify major renovation activities which would allow for the easy integration of energy conserving techniques and technologies. The contractor should be able to explain to the homeowner the implications of piggybacking retrofit work on the planned renovation. These could include extra time and costs, potential savings, improvements in thermal comfort, thickening of wall assemblies, etc.

3.1.2 Upgrading the Building to Remedy Problems and Related Retrofit Work

Structural, mechanical and associated problems often lead to the need for major renovation activities. The table below provides some guidance as to the type of retrofit work which can be integrated with the structural repairs.

Planned Renovation Work	"Piggybacked" Retrofit Work	Potential Implications
Waterproofing leaky basement and installation of new drain tile.	Install exterior insulation to grade or above.	Increased cost of insulation. Warmer basement. As much as 15% reduction in fuel bill.
Major roof repair.	Upgrade roof insulation by rebuilding roof or by adding new roof over top of existing sheathing.	Increased framing and insulation costs. Reduction of up to 10% in fuel consumption. Reduced icing on roof.
Urea Formaldehyde Foam Insulation removal from walls.	Upgrade wall insulation and air vapour barrier: a) in stud cavity with optional strapping; or b) rigid insulation and strapping on top of old plaster.	Increased framing and insulation costs. Reduced fuel consumption. Better moisture protection for walls. Potential need for central ventilation.
Major upgrading of house mechanicals.	Installation of higher efficiency equipment. Improvements to air distribution. Balancing of heating system.	Improved air quality. Reduced fuel consumption. Improved comfort levels.

3.1.3 *Upgrading Building Aesthetics and Related Retrofit Work*

Renovation activities will be performed to alter or improve the building aesthetics.. The table below provides some guidance as to the type of retrofit work which can be integrated with this type of renovation work.

Renovation Work	"Piggybacked" Retrofit Work	Potential Implications
Building residing.	New air barrier. Exterior wall insulation. Relocation of windows to maximize solar gains.	Tighter and warmer house. Potential need for central ventilation Reduced fuel costs Higher humidity levels.
Interior renovations.	Interior wall reinsulation. Upgraded ceiling insulation and air tightness	Tighter and warmer house. Potential need for central ventilation. Reduced fuel costs. Higher humidity levels.
Window Redesign and/or Replacement.	Improved air tightness. Better performing windows.	Reduced risk of frosting. Fewer drafts.

3.1.4 *Spatial Improvements and Related Retrofit Work*

Renovation activities will be performed to increase or add to the living space of the house. The table below provides some guidance as to the type of retrofit work which can be integrated with this type of renovation work.

Renovation Work	"Piggybacked" Retrofit Work	Potential Implications
Providing finished basement space.	Upgraded basement insulation.	Reduced heating costs. Greater comfort. Extra framing costs and insulation. Better moisture protection.
Upgrading attic space.	Upgraded ceiling insulation and air-vapour barrier, or if roof is raised or dormers added, maybe an exterior roof retrofit.	Reduced heating costs. Greater comfort. Extra framing costs and insulation. Better moisture protection.
Gutting of building interior	Upgraded wall and ceiling insulation and air-vapour barrier. Upgraded mechanicals.	Reduced heating costs. Greater comfort. Extra framing costs and insulation. Better moisture protection. Potential need for central ventilation.

3.2 ASSESSING THE HOUSE

Every contractor knows first-hand that no two houses are alike. While on the surface the exterior elevations, siding and even interiors are similar, what happens between the walls may be very different. Before focussing on any specific retrofit approach, the contractor should perform a detailed assessment of the house. The assessment should include, as a minimum, a determination of:

- foundation type and condition;
- house structural walls – framing type and condition;
- roof type and condition;
- any structural defects or moisture related problems;
- specific architectural features requiring attention;
- insulation levels existing in all areas;
- air tightness of the existing house envelope;
- codes, bylaws and regulations which might affect the retrofit plans; and
- the space heating and heat distribution system.

A thorough understanding of the existing condition of the house allows the contractor to design a suitable retrofit strategy. It will also assist the contractor in determining which work can be justified and what problems might arise.

When performing a visual inspection of the house, the contractor may want to analyse each component under the following criteria:

Energy Performance The existing insulation levels and the level of air tightness of each assembly should be determined. This will help to assess each building component and the potential energy savings.

While the knowledgeable contractor will have a pretty good idea of what happens inside walls, a more thorough assessment may be needed. There are several means of determining type, thickness and condition of the existing insulation, which include:

- removing electric outlet coverplates and probing behind the outlet box – **after the power has been disconnected**;
- cutting a hole in the wallboard in a hidden location (inside a closet or cupboard) or in an area which will be upgraded as part of the renovation; and
- removing a piece of exterior siding to assess the wall insulation from the outside.

Specifically, the contractor will want to assess the following aspects of the building envelope:

- type, thickness and condition of the insulation and therefore resistance value;
- settling or moisture absorption of the material; and
- feasibility of installing additional insulation in the existing cavity.

In some cases a thermograph can be taken of the house to determine the location and condition of the insulation. A thermographic scan using infrared film can also identify sources of air leakage. Another tool for identifing air leakage is the depressurizing door.

Moisture Performance Each component of the building should be assessed for its ability to deal with moisture originating from either inside or outside the house.

A visual inspection will allow the contractor to identify the majority of problems which might affect the house. Moisture problems that can be identifed by an interior inspection include the following:

- deteriorating window sills caused by condensation;
- water stains on wallboard or ceilings, indicating potential leakage from the exterior or condensation;
- flaking of paint or spalling of masonry surfaces, indicating a need for dampproofing;
- musty odours in house basements, indicating a need for improved dampproofing or waterproofing; and
- standing water or signs of water stains on the basement slab, indicating leaks.

The exterior inspection might identify moisture problems as represented by:

- deteriorating exterior sills and thresholds, caused by standing water;
- spalling or efflorescence of masonry surfaces at the top of the foundation wall, indicating rising damp;
- blistering paint or stucco, indicating trapped moisture in the wall cavity; and
- water stains, indicating improperly performing flashings.

Structural Performance Any structural flaws or weaknesses should be identified before new work is considered. The effect of the retrofit on the house structure should also be considered, including:

- the ability of the existing wall to support new loads, i.e., how and where will the retrofit be structurally supported; and
- the condition of the existing foundation of the house such as cracks, shifts, etc. should be assessed as to the cause and potential effect of the problem.

Architectural Features Architectural features which need to be saved and/or restored should be identified, recorded and photographed. These features may influence overall decision-making as to which retrofit strategy should be considered. The existing state of all components of the house should be noted.

Accessibility It is important to determine access to the component of the house, from both the interior and the exterior. The contractor may be influenced by a lack of available space or by difficulty in working around various obstructions.

3.2.1 *Assessing the House Foundation*

The building's foundation plays a major role in any whole house retrofit strategy. The foundation wall may need to be upgraded structurally, thermally, and for its moisture characteristics. All of these aspects should be noted and considered by the contractor.

Energy Performance Most older houses will be totally uninsulated as foundation insulation was not generally accepted until the mid-1970's. More recently, foundation insulation from the floor joists to 600 mm below grade has been incorporated in most building codes.

It will be necessary to determine the air tightness of the existing foundation walls if the contractor is trying to assess the benefits of basement retrofit work. The common air leakage areas which should be inspected include:

- the junction of the sill plate to the foundation;
- cracks in masonry foundations;
- penetrations through the foundation wall; and
- any windows and exterior doors.

Moisture Performance In inspecting the foundation walls for moisture problems, two levels of problems should be considered.

Major moisture problems include standing water in the basement caused by leaking walls or slabs, or seasonal flooding of the basement. While the contractor might not always see the problem, tell-tale signs would include stains on walls and slabs, excessively high relative humidity levels and signs of wet rot at the sills.

Minor moisture problems include spalling of interior surfaces, efflorescence on exterior or interior surfaces, and high basement relative humidity levels. The contractor may want to probe masonry walls to determine whether moisture problems have caused deterioration.

Structural Performance An inspection of the foundation walls for structural integrity will be part of the energy and moisture assessment. In addition to identifying cracks and faults in the masonry, a quick probing of the floor joists will permit an assessment of whether moisture or insects (termites, carpenter ants, etc.) have weakened the structure.

Architectural Features An upgraded and finished basement usually dictates against performing an interior retrofit. Outside elements should be considered for their implications on the retrofit design. These could include evenness of the exterior wall and the compatability of the appearance of the foundation wall with the main elevations of the house.

Accessibility The contractor should assess the limitations and expense which might be incurred in relocating or working around the following components.

- **Interior**
  - electrical outlets, wiring and service panel;
  - existing plumbing lines, wash tubs, taps, laundry equipment, DHW, etc.;
  - heating systems including the furnace and the distribution ducts and/or piping;
  - storage space, workshops, closets, stairs, etc.;
  - partition walls.
- **Exterior**
  - proximity to neighbouring buildings which might restrict access for mechanical excavation equipment;
  - landscaping around house, including prize roses, bushes and trees;
  - fuel line entrances, such as gas meter or oil tank fill pipe;
  - downspouts;
  - built-on porches, cement landings, stairs, sidewalks, paved driveways, etc.

3.2.2 *Above Grade Walls*

Work on the above-grade walls (either interior or exterior) has a significant impact on the appearance of the building. The retrofit of the walls creates a wider wall assembly and changes the appearance of the building. These changes might include new cladding, resized or relocated windows, upgraded interior finishes and a reduction in interior spaces.

The homeowner may have strong feelings about what features of the house are liked or disliked. The contractor's assessment of the walls should ensure that the homeowner's desires can be technically, aesthetically and economically integrated into the retrofit.

Energy Performance The contractor should attempt to examine the interior of the wall assembly to assess:

- the amount and type of insulation;
- the condition of the insulation and framing members; and
- the potential for convective air movement within the assembly.

The contractor should also assess the existing walls for air leakage paths. The following areas generally account for the major sources of air leakage:

- perimeter floor assemblies: behind baseboards, beneath subfloors, between wall plates;
- window openings: between window jamb and rough stud opening;
- electric outlets and switches; and
- penetrations in the envelope: exhaust fans, fireplaces, services, etc..

Finally the contractor should assess the ability of the walls to deal with moisture. The existence of a vapour barrier and the condition of exterior flashings may have an effect on the decision-making.

Structural Performance The ability of the existing house walls to support new loadings imposed by retrofit work should be assessed. Where exterior retrofit work is directly fastened or suspended from the walls the contractor will want to evaluate the following:

- type of construction (solid wood or masonry, or frame);
- type of framing (platform, balloon or plank framing);
- spacing of studs; and
- type of sheathing.

Each of the above issues might have an effect on the retrofit strategy proposed.

Most interior retrofit work is non-load bearing and therefore does not impose significant dead-loads on the house structure. The only issue relating to interior retrofit work might involve upgrading existing defects before the retrofit work is begun.

Architectural Issues In most cases, exterior retrofit work is designed to upgrade an otherwise deteriorating building facade. Where decorative trim or mouldings need to be relocated or replaced, the contractor should assess the work.

The most important issue affecting potential exterior retrofit work relates to the junction of the retrofit wall with the existing soffit or roof rafters. Design of the exterior retrofit may be influenced by the overhang of the roof rafters. Ideally, the contractor will find that the overhang can allow for the new exterior wall while permitting adequate soffit ventilation. In the worst case, the contractor will need to extend the existing rafters, sheathing, and roofing to allow for the new retrofit wall. Inspecting the existing overhang and the potential work involved in altering the roof line is an important element of the design process.

The main issue affecting interior retrofit work relates to the reduction of floor area caused by thicker walls. The proportioning and usefulness of rooms and hallways which have been reduced in size by as much as 200 mm must be assessed by the contractor and homeowner.

Accessibility The contractor should determine the potential difficulties which the retrofit process may impose on the construction process. While the ideal site would allow for the installation of a totally continuous blanket of insulation and a totally seamless air barrier, the realities of existing housing suggest difficulties will arise. The following items should be considered as they affect the design and construction of retrofit work:

Interior
- Partition walls, stairs, cupboards, and floor assemblies will obstruct continuity.
- Plumbing lines on exterior walls will need to be relocated if adding interior insulation.

Exterior
- Lot line restrictions affecting setbacks and side lot clearances must be determined and noted.
- Electrical service mastheads, downspouts, etc. may need to be relocated.
- Proximity to adjacent buildings may restrict access to spaces.
- Multi-storey buildings can impose accessibility problems.

3.2.3 *Roofs, Attics and Ceilings*

Inspection and evaluation of the existing condition of house roofs, attics and ceilings will provide an appreciation of the remedial work required and the potential impact of improved thermal performance. Planned renovations or alterations may be the major determining factor as to what retrofit options are considered.

Accessible attics are easy to assess through the attic hatch. Flat roofs and cathedral ceilings are more difficult. The best place to evaluate these roofs is through the soffit by removing some of the material.

Energy Performance Most houses have some insulation in the attic or roof joist cavities, although in older housing the material may range from mineral wool to sawdust. The contractor should attempt to assess:

- the amount, type, and RSI value of the material;
- the existence of a vapour barrier;
- the condition of the insulation and framing members; and
- the existence of a weather barrier at the soffits.

Air leakage into roof cavities from the house interior can lead both to excessive heat loss and moisture accumulation. The major sources of air leakage into house attics include:

- ceiling electrical receptacles, recessed lights and wiring running through wall top plates;
- plumbing vent stack entry into attic;
- cracks around the top plate of interior partitions;
- the attic hatch; and
- the junction of fireplace or furnace chimneys and the house ceiling.

Air leakage locations should be noted and sealed before reinsulation.

Moisture Performance The first line of defence for the attic s a good air seal. Ventilation is used to remove any water vapour that does get into the attic space. The contractor should inspect for dampness or dusting of insulation around the main leakage areas.

In accessible attics, the contractor should check to see that there is air movement. In accessible attics, this is usually from the soffit to the vent. Ventilation of flat roofs and cathedral ceilings can be determined to some extent by exposing the cavities at the soffit.

Finally, the contractor should note any failure of the building's roofing system. Leaks in the roof can often be traced by stains on the sheathing. The contractor should inform the homeowner of required remedial work.

Structural Performance When adding insulation above the existing roof is a consideration, the contractor will need to assess the ability of the roof structure to carry the extra dead load. Rafter spans, dimensions, and type of lumber will need to be inspected to ensure that the members have the ability to carry the new loads.

3.2.4 *Assessing the House Mechanical Systems*

Major renovation and/or retrofit work will allow and often require an upgrading of the mechanical systems so that they will meet the new requirements of the home. In performing a visual inspection of the house, the contractor will want to make a note of the following components, and how they affect proposed renovations and retrofit measures.

Electrical
- Determine amperage of main service panel and number of available circuits.
- Assess the age and condition of the existing wiring.
- Note the location of the service inlet and panel.

Plumbing
- Assess the age and condition of the house supply.
- Assess the age and condition of the drainage system.

Ventilation
- Determine the location of all kitchen and bathroom vents and assess what would be required to centralize ducting in the basement.
- Assess potential location of a controlled ventilation system.
- Assess the potential for integrating a central ventilation system with the heat distribution network.
- Assess the potential for tightening the house.

Heating
- Note the capacity of the house space heating system such as burner capacity for oil and gas systems and/or total wattage of electrically heated units.
- Note the distribution system - forced air or hydronic heating.
- Assess the distribution system for air leakage (are seams taped?) and for heat loss (are hydronic systems insulated?);
- Determine how combustion air is provided.
- Note signs of backdrafting from the furnace and domestic hot water (DHW) tank. This would include soot around the burner or corrosion around the barometric damper.
- Note location and type of thermostat in house.

While most major alterations to the house mechanical systems will be performed by qualified tradesmen, it is important that the contractor has an overview of what is required.

3.3 *ASSESSING THE COST/ BENEFITS*

Determining the costs and potential benefits of specific retrofit measures on an existing house will require a thorough understanding of job costing, heat loss equations, regional climatic conditions, fuel price scenarios, interest rate fluctuations, and the value of increased comfort and security to a homeowner. The knowledgeable contractor will be able to determine his construction costs, and may be capable of determining heat loss equations.

The contractor should be aware of the aims and objectives of the clientele. To a large segment of the population, cost/benefit analysis is meaningless. To homeowners who have decided to spend the rest of their days in that specific house, market value and payback may be far less important than comfort and security. As anyone involved in the construction industry is aware, homeowner decision-making is not always premised strictly on issues of cost efficiency.

3.4 DETERMINING POTENTIAL ENERGY AND DOLLAR SAVINGS

Heat loss calculation procedures for determining the rate of heat loss in the house are described in Chapter 2. The rate of heat loss, as expressed in watts, represents the total of the conductive and air leakage heat losses per second for a given temperature difference. To make this number more meaningful one needs to be able to translate the rate of heat loss at a given instant into the heat losses accumulated over a week, a month, or even over a heating season. To do this, we need to know the duration of the time period and the temperature difference between inside and outside over that same time period. As described in Chapter 2, the most convenient means of analysing these factors is by using local degree-day (DD) data as published in building codes. With the available degree-day information at hand, the contractor can calculate the specific time framework and determine the number of watts of heat the house would have required over that period.

3.4.1 *Manual Heat Loss Equations*

By following the procedures established in Chapter 2, one can determine conductive and air leakage heat losses. The sum of the conductive and convective losses provides the rate of heat transfer in watts or joules/sec. If one is interested in calculating the heat losses from a building over the heating season, two figures are required. First, one converts the losses from the building in joules/sec. to joules/day by multiplying by the number of seconds in an hour (3600), and then by the 24 hours in the day. Next, one looks at local degree-day figures for the heating season as published in building codes. To determine the total losses over the course of the heating season, the following equation is used:

Q_{annual} = (The sum of U x A for the house envelope + the rate of heat loss from air exchange) x 3600 x 24 x Degree-Day

where;
Q_{annual} is expressed in joules/year;

U x A is expressed in joules per second per °C;
Air exchange losses are expressed in joules per second per °C;
3600 x 24 represents the number of seconds in a day, and;
Degree-Day is expressed in °C- day/year.

To provide a more accurate view of the overall energy flows in the house the contractor needs to be able to analyse not only the losses, but also the different heating inputs to the building. Without accounting for free heat gains from solar inputs and internal heat gains, heat loss calculations will not adequately reflect the operation of the house. Determination of the effects of solar inputs, which can be a long and complicated procedure, is greatly assisted by computer analysis.

The contractor will want to translate heat loss quantities into how it affects the dollars and cents. To perform this calculation the contractor will need to know the type of fuel, the cost of the fuel to the homeowner and the efficiency of fuel combustion. These factors will vary considerably from region to region. The contractor may need to look at recent fuel or electrical bills to ascertain the regional prices. Combustion efficiency can be estimated by a knowledgeable contractor or can be tested by a furnace mechanic.

3.4.2 *Computerized Heat Loss Equations*

To determine the potential savings resulting from the total retrofit, the contractor would need to perform two heat loss calculations – one for the house in its existing state and a second for the retrofitted house. This amount of work is time consuming and can be subject to calculation errors. A better solution would involve the use of existing computer programs. The most accessible of these programs is HOTCAN, which has now received wide circulation through Energy, Mines and Resources, Canada (EMR) and through the Canadian Home Builders' Association (CHBA). The contractor will still need to do accurate take-offs of the building areas and will need to be able to identify the current and projected RSI values of the different components of the house envelope.

The computer printouts of the existing and retrofitted house should be carefully analysed. They will provide the contractor with the heat loss through the different components of the house, and can provide an estimate of the actual dollar cost of the different fuel types in the area. The contractor should compare the printout of the existing house with any fuel consumption records which the homeowners have kept. Where there is adequate correlation between the predicted and actual energy consumption the contractor can be assured that the predicted reductions in fuel consumption will be reasonably accurate.

3.4.3 *Totalling the Potential Savings*

By comparing the before and after retrofit predicted fuel consumption figures, one will have an idea of the dollar savings to be gained from the retrofit. While these figures may be predicted either manually or by computer, they should be viewed only as estimated savings. The contractor will need to be aware of the different factors which might lead to a difference between the predicted savings and the actual savings. The calculated heat losses and fuel consumption can be dramatically altered by several factors, including:

- altered use of the house caused by more or fewer occupants;
- changes in the operating conditions of the house caused by lowered or raised thermostat settings;
- running the house with open windows or greater air exchanges than predicted;

- changes in fuel prices;
- changes in the relative severity of the weather from one winter to another; and
- improperly applied insulation and air sealing techniques.

The contractor should be aware of the potential problems resulting from falsely raising expectations of overly large fuel savings. While each and every house will provide different results, the experiences gained from performing a number of retrofits will provide the contractor with a better background on the potential fuel savings resulting from a variety of retrofit measures.

The contractor and homeowner will be confronted with a variety of measures for determining the cost effectiveness of the proposed retrofit measures. Most simply presented to the homeowner will be the concept of **simple payback**, the number of years it will take to pay off the capital invested in the retrofit energy savings. Where the homeowner has invested $10,000 at a projected saving of $1,000 on the fuel consumption, the simple payback would be 10 years. While this concept is the most easily understood, it leaves open questions about the projected costs of fuel, the fluctuating costs of borrowing money to have the work done, changes in property valuation, and the rate of return on the invested dollar. A proper evaluation of the retrofit investment would involve a more complex procedure, which is equally prone to misjudgements in forecasting interest rates, fuel prices, and other related investment considerations.

3.4.4 *Softer Benefits*

Many homeowners and contractors will focus their attention on the potential dollar savings resulting from the retrofit work. Field experience suggests that the average homeowner may be equally concerned with non-quantifiable benefits. These benefits, which are seldom viewed on a monetary basis, will include many of the more convincing sales features, including:

- greater control of the interior relative humidity;
- reduced drafts and dust throughout the house;
- more even temperatures throughout the house; and
- a quieter home interior.

4

ASSESSING THE OPTIONS - INTERIOR VS. EXTERIOR

Many homeowners consider that insulating attic cavities and installing some weatherstripping constitutes a complete retrofit strategy. The whole house retrofit approach goes well beyond this, resulting in a major alteration in house performance, appearance, and even size. While each house may demand different approaches to retrofitting, most total retrofit techniques will share certain characteristics.

Whole house retrofit work can be performed from the outside (wrapping the existing walls and roof) or from the house interior (providing an insulated liner). The decision as to which strategy to employ will be guided by the house, by the homeowner and, inevitably, by the cost. In many cases a combination of exterior and interior work will result in the best approach.

This chapter provides an overview of the different retrofit options, highlighting the advantages and disadvantages of each approach. Chapters 5 through 9 of the Manual provide detailed discussion of each of the specific retrofit techniques.

4.1 EXTERIOR RETROFIT OPTIONS

As with any retrofit work, exterior retrofit is most easily justified as part of ongoing renovation activities. Obvious exterior renovation activities which allow for the integration of energy conservation work include

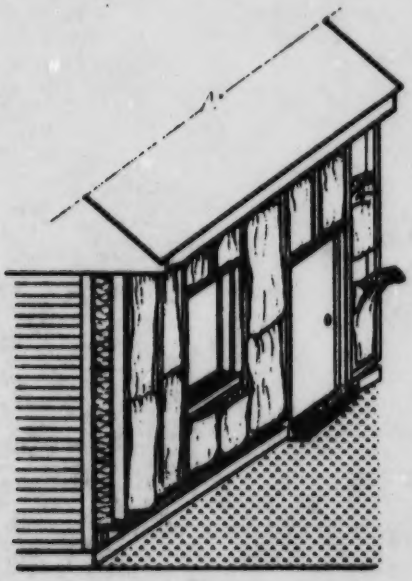
- excavation around house foundation walls for waterproofing or dampproofing;
- recladding of the existing house walls;
- major structural alterations to exterior foundation and house walls;
- major reconstruction of the house roof; and
- major architectural alterations to the house.

All aspects of the thermal envelope can be retrofitted from the exterior. While the mechanics of the job will vary, several benefits of exterior retrofit work apply to all approaches.

4.1.1 Advantages of Exterior Retrofit

- The retrofit work can be easily integrated with other renovation work. The incremental cost of improving air tightness and adding insulation is most easily justified when the cost of the new cladding, roofing or waterproofing has already been accounted for.

- Providing an airtight seal to the envelope is much easier when done from the outside. Penetrations and discontinuities such as partition walls, floors, stairs, cupboards and closets will cause difficulties in sealing from the inside. Wrapping the exterior of the house can result in high levels of air tightness.



Exterior Insulation

- Installation of a continuous thermal insulation layer is made easier on the exterior.

- Exterior retrofit work minimizes disruptions to the house and its occupants. The homeowners can remain in the house throughout an exterior retrofit with only a minimum of disruption and annoyance. Construction time can be greatly reduced when working from the outside. Interior floor area is not reduced.

- Exterior retrofit can keep the thermal mass of the building away from the cold exterior. This is particularly true in relation to the house foundation walls where the warmer foundation is less susceptible to swings in soil temperatures. The thermal mass of the house (concrete, brick, etc.) is on the interior and can be useful in controlling temperature fluctuations caused by solar heating or a wood stove.

- Exterior retrofit work can allow for alterations and improvements to the existing facade of the building.

4.1.2 Disadvantages of Exterior Retrofit

Exterior retrofit work can also pose some problems for the homeowner and contractor. Some of the limiting factors and disadvantages of exterior retrofit work include the following.

- The cost is relatively high. Exterior retrofits can be an expensive alternative unless the cost of residing is already assumed. On multi-storey buildings, scaffold work may increase costs.

- There are potential lot setback problems. Extending the house an additional 150 to 200 mm may be difficult or impossible because of lot line restrictions or narrow driveways. This could justify the use of board insulation with higher insulation values per unit of thickness.

- There will be changes to the exterior facade of the house. These changes are an important consideration for historic buildings or for those buildings with interesting architectural features or brick siding.

- Exterior features could prevent the work. Porches, stairs, driveways, sidewalks, prize rosebushes or trees can all make continuous exterior insulation either difficult or expensive.

- Exterior insulation is weather sensitive. Work scheduling can be dictated by cold, windy or rainy weather.

- When the retrofit assembly extends beyond the roof line, the roof will need to be extended to allow for adequate soffit ventilation.

4.2 INTERIOR RETROFIT OPTIONS

Retrofitting insulation from the inside of an existing building can be easily incorporated into planned renovation work. It is easier to justify piggybacking energy conserving techniques and products onto house renovation activities. Obvious interior renovation activities which may present an opportunity for retrofit work include:

- upgrading of house basements to living space, recreation rooms, extra bedroom, etc.;
- refinishing of walls to cover faults in plaster or wallboard;
- major rewiring, replumbing or alterations to the house heating/cooling systems;
- major structural upgrading or alterations; and
- major renovation of interior floor plans.

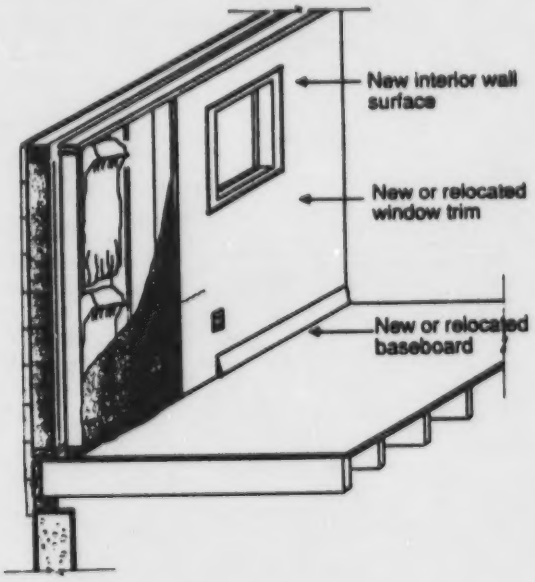
Each component of the house: basement, above grade walls, and roof, will require separate design criteria and construction processes.

4.2.1 Advantages of Interior Retrofit

- The work is integrated with other interior renovation activities such as removing walls, replastering, etc.
- It is not affected by climate. Because the work is indoors, it can be done throughout the year.
- The exterior facade can remain intact. Maintaining the outside look of the house is very important for many buildings.
- It allows upgrading of mechanical and electrical services since, during retrofit, there is access to services. Ducts can be run and taped, plumbing can be upgraded and old wiring can be replaced and expanded.
- Construction is easier. Conventional framing is used and there is minimal need for ladders, scaffolding, etc.

4.2.2 Disadvantages of Interior Retrofit

- It is difficulty to install a continuous air barrier. Interior features such as partition walls, floor junctions, stairs, etc. can make running a continuous air barrier difficult or impossible.
- It may be difficult to install high levels of insulation. Those areas where it is difficult to install an air barrier can also be difficult to insulate well. Features such as doorways and halls can limit the thickness of the new wall.
- The work will disrupt the house. A full interior retrofit can render a house uninhabitable for the duration of the job.
- The retrofit may limit floor space. Interior floor space, as well as headroom, can be reduced with interior insulation. Often insulation levels have to be sacrificed if space is at a premium.
- The retrofit will result in changes to the interior of the house. Interesting features, such as mouldings, etc. may be destroyed or covered up with interior renovation.



Interior Insulation

CONSTRUCTION OVERVIEW

The experienced contractor will have little problem in integrating retrofit work into conventional operations. The majority of the work utilizes standard materials, labour and construction sequencing.

This section of the manual has been included as a refresher for contractors who have already been involved in the energy-efficient construction field, and as an introduction for those not familiar with the field.

Section 5.1 provides an overview of the different materials used in retrofit work. It is important to become familiar with the various options for attaining high insulation levels and airtightness. While most of the materials are commonly available, several have only recently been introduced into the market.

On-site experimentation is often a good means of determining the materials and techniques that best suit each contractor's operations. However, a fundamental knowledge of the properties of the various materials, and their benefits and limitations, is important to ensure better performance.

Section 5.2 provides the contractor with an overview of the implications of total retrofit work on the construction process. This section covers labour requirements, implications on job sequencing, supervisory requirements, and some job costing guidelines.

While it is not the intent of this manual to dictate how one should run a business, various construction procedures which will affect the day-to-day company operation are highlighted.

5.1 MATERIALS

The contractor performing retrofit work will need to consider a range of conventional and new materials for the job. Any decision-making concerning the materials to be used should be influenced by the intended use of the material, the manufacturer's specifications, and its availability and cost.

Performance

The contractor must be aware of the qualities of the materials used. For instance, uncured dampproofing can ruin some rigid board insulations, and some caulks do not adhere to concrete. A prior knowledge of the manufacturer's specifications and applicable standards is necessary to ensure successful installation.

Availability

Whole house retrofit work involves the use of some specialty items and newly developed materials which may not be locally available. These items may require extra time for product sourcing and delivery and may be subject to periodic shortages. Advance plannning and good communications with suppliers will prevent on-site delays due to missing materials.

Cost

Determination of cost-effectiveness should be based on installed costs, including hidden costs such as:

- special handling requirements (storage or on-site protection);
- ease of handling (health and safety requirements);
- special installation requirements (temperature limitations, curing time, possible wastage), structural implications, surface preparation (i.e. priming, cleaning, sealing);
- effects on construction sequence;
- special requirements for site preparation, mechanical support, protective covering;
- special accessories required, such as primer, tape, fasteners, adhesives, protective coverings and finishes; and
- availability, including late delivery and extra transportation costs.

Because of these hidden costs, it is often easier to compare the cost effectiveness of assembled systems rather than individual components.

Keeping Up-to-date

It is important to keep up-to-date with new products and specifications. Manufacturers' literature is one source of information. The Canadian Home Builders' Association has published *A Catalogue of Energy Conserving Products and Services* which provides background information on many new products. Many trade publications and periodicals now focus on energy efficiency and renovation. A listing of useful sources of information is included at the end of Appendix B.

5.1.2 Insulation Materials

Insulation materials have been developed to meet a variety of design and site conditions. The choice of which material to use will be based on a number of considerations, including:

- thermal resistance, RSI;
- cost, most easily compared using $\$/RSI/m^2$;
- ease of installation, fastening requirements;
- resistance to air flow;
- permeance, ability to allow water vapour diffusion;
- water resistance and settling;
- stability and expected lifetime; and
- health and safety considerations.

Material properties for the insulations most commonly used in advanced retrofit work are summarized in Table 5.1. The notes that follow will provide some guidelines regarding suitable retrofit applications, special handling requirements and limitations of the materials. For more complete information, the reader is advised to consult the manufacturers' specifications. There are also Canada Mortgage and Housing Corporation (CMHC) *Building Materials Evaluation Reports* which describe the material's characteristics and test results. These reports are available for a price from local CMHC offices.

TABLE 5.1

MATERIAL	RESISTANCE TO VAPOUR DIFFUSION	RESISTANCE TO AIR FLOW	RSI/mm
cellulose	low	good	0.025
glass fibre			
- loose	low	low	0.021
- batt	low	low	0.022
rigid glass fibre			
above grade	low	high	0.031
below grade	low	n/a (depending on facing)	0.031
polystyrene			
Type I	low	medium (depending on installation)	0.026
Type II	low	high	0.027
Type III	high	high	0.027
Type IV	high	high	0.035
polyurethane	high	high	0.042
polyisocyanurate	high	high	0.042
phenolic sheathings with water repellant coating	low	high	0.030

Loose and blown insulation is available in different materials and for use in different densities. When installing the insulation, care should be taken to ensure that

- the insulation does not block soffit vents;
- the insulation is not used around heat sources such as chimneys or recessed light fixtures;
- the material is installed at the proper density;
- the material does not compress other insulation materials; and
- if there are wet or potentially wet conditions, the insulation used is designed for that application.

Cellulose can be poured or blown and is most suitable for attics, walls or closed cavities. Cellulose provides a good air seal when installed to the proper density.

Loose fill glass fibre and mineral wool is most commonly applied in attics.

Glass fibre and mineral wool are available as loose fill, flexible batts or semi-rigid boards. The materials are resistant to water damage, and are generally non-combustible. For comfort and safety, protective clothing and masks are required for installers.

Friction fit batts are available to fit standard-sized stud and joist openings. They are most commonly used on interior cavity walls, on newly-framed interior stud walls and with exterior curtain walls or truss wall systems. Batts should be installed snugly without gaps that would permit convective air currents to form in the wall. Particular care needs to be taken when batts are applied vertically.

Semi-rigid glass fibre boards have been developed for specialty applications. One type is an exterior non-structural sheathing faced with an air barrier of spunbonded olefin; this is most often used in new construction. The second type of board is used as exterior basement insulation. Semi-rigid glass insulation can allow water to drain to the perimeter drain tile and must be installed vertically to the footings without horizontal seams.

Rigid polystyrene insulation is available in four densities: Type I, Type II, Type III and Type IV. All four types can be used as interior foundation or above-grade wall and ceiling insulation. Type I is not permitted in exterior below-grade applications. Type II is suitable for use below grade in well-drained soils. The high compressive strength and low water absorption of Type IV makes it especially suitable for below grade application. A specialty board with a water-draining surface is available for exterior foundation applications.

When installing plastic insulation, the following considerations apply:

- The material should be protected from sunlight, solvents, and coal tar products which can degrade polystyrene.
- Codes require that polystyrene for interior use be protected by a material mechanically fastened to the structure.
- When the material is applied to a masonry wall, a smooth surface is required to prevent gaps behind the insulation and resultant convective heat loss.

Phenolic sheathing, rigid phenolic board, is used mainly as exterior sheathing in new construction. This material is water repellant but vapour permeable; it does not act as a vapour barrier.

Polyurethane and polyisocyanurate are high performance/higher cost insulations that are most often used where space is limited. Some rigid boards are available with aluminum foil or kraft paper facing; others may be bonded by the manufacturer to a siding material. Typical applications for board stock include exterior sheathing and roof insulation.

Polyurethane is also available as a spray-on material. In this form it may be used as both an air seal and insulation to fill large gaps, such as air leakage points in the attic or between the window frame and rough opening. It is available in single-component small containers, or as two-component bulk material.

Polyurethane must be protected from sunlight and is susceptible to damage from moisture. It must be protected on the interior by a fire-rated covering mechanically fastened to the structure.

5.1.3 *Protective Coatings and Sidings*

A covering is required above grade over exterior foundation insulation to protect the material from sunlight, water damage, insects and vermin, and accidental impact. Several new materials have been developed for this application. Several of the products involve trowelled-on materials intended to eliminate the two or three part parging process. A protective covering should be selected with the following considerations:

- installed cost;
- ease of installation;
- appearance; and
- durability and ease of repair.

5.1.3.1 *Surface Applied Coatings*

Lath and Parging This traditional system uses a two-step process. The expanded metal lath is mechanically fastened to the foundation through the insulation and two or three coats of cement based parging are applied over the lath. While this is the most labour intensive system, it is the one most familiar to the trades.

One Step Coating Several coatings which do not require metal lath have been developed for use over insulation. These materials require minimum surface preparation and are less labour intensive. They are not as resistant to impact as the lath and parging or the rigid board materials.

5.1.3.2 *Rigid Boards*

Several types of board materials may be used as foundation coatings:

Asbestos cement mill board is compatible with all types of foundation insulation and is relatively easy to install using mechanical fasteners. It is brittle and easily damaged. Care should be taken when cutting and handling this material because of the asbestos fibre content. Where possible, other materials are recommended.

Pressure treated plywood may be applied over all types of foundation insulation using mechanical fasteners. It should only be used in well-drained soils. A surface finish is not necessary but may be desired for aesthetic reasons.

Glass fibre reinforced panels have been developed for use over rigid foam insulations. They are resistant to ultra violet degradation, impact and weathering.

5.1.4 *Insulation Accessories*

Three types of accessories have been developed for use with insulation: mechanical fastening systems, adhesive fastening systems and soffit baffles.

Mechanical Fastening Systems Proprietary fastening systems have been developed for attaching rigid board insulation to masonry walls. These systems can also provide a fastening surface for metal lath or other finishes without the necessity of strapping.

Adhesive Fastening Systems Two types of adhesive are available for fastening rigid board insulations. The mastic or synthetic rubber type is used to fasten rigid polystyrene. It is commonly called foam and panel adhesive. An asphalt-based adhesive can be used for fastening rigid glass fibre to masonry.

Soffit Baffles The ventilation air path from the soffit to the attic may be blocked by shifting insulation accumulating at the eaves. Baffles have been developed which attach to the rafters at the eaves, providing an unobstructed path for ventilation air. These baffles may be made of cardboard, plastic or rigid foam and are available in sizes to fit various rafter spacings. Some soffit baffles can also restrict the flow of outside air through the insulation materials.

5.1.5 *Air Sealing Materials and Vapour Barriers*

As discussed in Chapter 2, building research has led to a better understanding of the requirements for air barriers and vapour barriers.

An air barrier
- **must be continuous; and**
- **must be structurally able to withstand wind loading.**

A vapour barrier
- **should be located toward the warm side of the envelope; and**
- **need not be continuous.**

An air-vapour barrier
- **must be continuous** (when one material performs both functions).

Some materials are suitable for use only as an air barrier or vapour barrier while others can serve both functions if they are installed in a continuous manner; that is, all edges, seams, holes and penetrations are sealed. The most commonly employed systems in total retrofit work use a polyethylene air barrier and vapour barrier or a drywall air barrier with a paint or membrane vapour barrier.

5.1.5.1 *Air Barrier and Vapour Barrier: Sheet Materials*

Polyethylene is the most commonly used material which combines the features of an air barrier and vapour barrier. When installed with sealed seams and edges and sealed to all penetrations, it provides a good air barrier, with good vapour barrier characteristics. With increased understanding of the importance of a continuous air barrier, more emphasis has been placed on choosing an appropriate type and grade of this material to ensure performance and durability.

Polyethylene sheet is produced in a variety of grades depending on the resin used. The lowest grade is made from recycled resins and may exhibit marks, bubbles, opaque areas and even pinholes. Material for construction use should be manufactured from virgin resins. In general, the clearer the sheet, the better the product. Polyethylene is subject to degradation from exposure to ultra-violet light (sunlight). It is also susceptible to thermal degradation when exposed to high temperatures. The most durable polyethylene is made with resins which include ultra-violet stabilizers and anti-oxidants. Carbon black polyethylene and a clear, UV-stabilized polyethylene that is used in the greenhouse industry also offer resistance to ultra violet degradation.

Polyethylene is manufactured in various thicknesses. Common thicknesses used in the building trades are 0.05 mm, 0.10 mm and 0.15 mm. Since polyethylene is subject to punctures, tears and abrasions, the thicker (0.15 mm) material should be used for the air barrier.

Aluminum foil sheet has a very low permeance rating. It is also resistant to the passage of air and may serve as a combined air barrier and vapour barrier where it is installed in a continuous manner. Aluminum foil must not be installed where it is in contact with moisture from masonry material.

Foil is susceptible to punctures and tears. Its brittleness makes it more difficult to work with than polyethylene and the narrow roll size requires more seams. These reasons and the added cost of the material limit its use as a combined air barrier and vapour barrier.

Aluminum foil as a backing to gypsum board can provide effective vapour retarding characteristics.

5.1.5.2 *Air Barrier and Vapour Barriers: Rigid Materials*

Low permeance rigid materials can also be used as a combined air barrier and vapour barrier when installed on the house interior. They act as natural vapour barriers and, if installed in the correct manner, they can also act as air barriers. The seams and edges of the sheets must be sealed, any penetrations sealed to the sheets, and the sheets must be joined to other air barrier components of the envelope. Polyisocyanurate and polyurethane rigid board insulations are available with foil facing on one or both sides. With the foil facing, these insulations may serve as a combined air barrier and vapour barrier, as can extruded polystyrene if installed properly as a system. Rigid board material is primarily used in areas which are difficult to access, i.e., between floor joists.

Foil-faced drywall may serve as a combined air barrier and vapour barrier when installed using the drywall air barrier method. The foil backing provides the vapour barrier while the drywall acts as the air barrier.

Polystyrene insulation, types III and IV are rigid board insulations that are air and vapour resistant. When installed in a continuous manner, they may serve as a combined air barrier and vapour barrier.

Plywood or waferboard (exterior grade) is another rigid material which is both air and water vapour resistant. Application of the plywood for this function is similar to the drywall air barrier method (discussed below). More commonly, it is used as a sub-flooring material that is sealed to the wall finish.

5.1.5.3 *Air Barriers: Rigid Materials*

Some techniques use a high permeance material such as drywall as the air barrier. The vapour barrier is provided by a separate material.

Drywall is a familiar building material that is resistant to air flow. When used as an air barrier, continuity can be provided by caulking and gasketing where the drywall meets other rigid, air resistant building materials. Care must be taken to seal all drywall seams and all service penetrations in the drywall.

5.1.5.4 *Air Barriers: Sheet Materials*

Spun bonded polyolefin is a material made of polyethylene fibres and is resistant to air flow but allows free movement of water vapour. Spun bonded olefin is most suitable as an exterior weather barrier. For building assemblies using this material, a separate interior air barrier and vapour barrier must be provided. In new construction, the material can be used to make joist headers airtight by wrapping it around the joists and sealing it to the wall air barrier.

5.1.5.5 Vapour Barriers

Where the continuous air barrier is provided by materials that are vapour permeable such as drywall or polyolefin, a separate vapour barrier will be required on the warm side of the insulation.

Interior surface finishes can be used as a vapour barrier. These include aluminum-based, asphalt-based, and alkyd or oil-based paints. In addition, special vapour retarding paints have been developed with low permeability.

Other materials commonly used as vapour barriers can be used, such as polyethylene or extruded polystyrene. If an air barrier is already provided, these materials do not have to be installed in a continuous manner.

Some other building materials such as asphalt-coated or laminated papers may also serve as vapour barriers.

5.1.6 Air Barrier and Vapour Barrier Accessories

With increased understanding of the importance of airtight construction, a number of products have been developed to provide continuity of the air barrier, particularly caulkings, gaskets and tapes.

5.1.6.1 Caulking

Caulking materials are flow-in-place sealants that have been developed with a range of properties to meet most site conditions. The most commonly used types are acoustical sealant, acrylic latex, butyl rubber, polysulphides and silicone. These materials vary in

- adhesion and elasticity;
- service temperature and weathering characteristics;
- priming and curing requirements and emissions;
- durability; and
- compatibility with other materials.

For most applications where caulking is hidden in the building structure, it is recommended that materials with the longest service life be selected.

Variations in a material's property exist from brand to brand and manufacturers' specifications should be used in product selection.

The following factors should be considered when selecting a caulking material for a particular application:

- size of the joint (if greater than 6 mm, a backer rod will be required);
- expected joint movement;
- surfaces to be sealed; and
- the joint environment, i.e., exposure to weather, temperature, etc.

The capacity to bond to adjacent materials is an important consideration in caulking selection. The chart below provides a summary of typical applications.

Application and Suitable Sealant Types

Wood to wood
All acrylic sealants work here if the gap is less than 9 mm. Silicone sealants are used for gaps greater than 9 mm.

Wood to masonry
Butyl rubber is used for gaps up to 12 mm; polysulphide for gaps up to 19 mm and for damp conditions. Needs priming of surface.

Wood to metal
All acrylics can be used for gaps up to 9 mm; butyl rubber for gaps up to 12 mm; silicone sealant for gaps up to 25 mm and for gaps that are expected to display large movement. Urethane foam sealant can be used for gaps above 25 mm but will not be effective if there is large gap movement.

Masonry to masonry
Butyl rubber is used for gaps up to 12 mm; polysulphide for gaps ranging from 9 mm to 19 mm; grouts and special water-stop fillers for gaps over 19 mm. Polysulphide is a good choice where there is significant gap movement. Surface priming is required.

Polyethylene
Acoustical sealant is one of the few materials that will provide an effective seal to polyethylene. Note that this is not an adhesive, and should be supported mechanically by screwing, nailing or stapling another material to the structure, i.e., wood-strapping, tape, etc.

High temperatures
Silicone sealants are effective at fairly high temperatures, but their temperature limit should not be exceeded. Room Temperature Vulcanised (RTV) silicone sealant is suitable for high temperatures, but requires very specialised application procedures. High temperature stove sealants or muffler cement can be used.

High humidity
Most silicones are suitable. Water-based vinyl acetate sealant is acceptable if it has fungus and mildew retardants.

Electricals
Specialty electrical caulks can be used to prevent air leakage through the service inlet to the house. They are installed on the interior of the electrical service conduit where it enters the service panel or at the entrance well of the conduit on the outside of the house. Local electrical codes must be followed.

Caulking performance will depend not just on selection but also on installation. With these fluid materials, it is important to follow the manufacturer's recommendations regarding

- surface preparation;
- installation temperatures;
- priming and curing requirements;
- proper application of the caulking bead;
- tooling of the bead; and
- compatibility of materials.

For more detailed information on the material properties of caulking and correct application methods, refer to *Air Sealing Homes for Energy Conservation*, listed in Appendix B.

5.1.6.2 Gaskets

Gaskets are flexible materials of closed or open cell foam available in a ribbon or a cylindrical profile. Preformed gaskets are also available to fit over electrical outlets. Gaskets are designed to seal under compression and to tolerate some joint movement over time. Gasket materials vary in

- compressibility and resiliency;
- permeability;
- chemical composition and stability;
- durability and profile integrity;
- ability to withstand wind loads; and
- compatibility with other materials.

Gaskets present two advantages over caulking: ease and speed of installation, and suitability for cold weather construction. The types most often used for various applications are noted below.

- **Ribbon format** is used for sealing junctions of structural members such as foundation wall and sill plate.
- **Cylindrical format (backer rod)** is most often used as a support and backer for caulking material in large joints. This type is also used to seal compression joints in the drywall air barrier system.
- **Electrical gaskets** are used for outlets.
- **Site fabricated gaskets** of butyl rubber sheet material are used to seal plumbing or mechanical penetrations at the foundation wall or attic.
- **Ethafoam sill gasketing** is used at the sill plate

5.1.6.3 Tapes

Construction tapes provide an adhesive with a flexible backing. Backings may consist of polypropylene, foil, foil-faced paper, cloth, or metalized cloth. Depending on their composition, tapes will vary in

- tensile strength;
- elongation;
- adhesion to various materials;
- durability and temperature resistance; and
- pliability and tack at low temperatures.

Tapes are suitable for sealing joints in sheet materials where there is little or no expected movement. Tapes should be selected with the following considerations:

- materials to be joined;
- surface preparation required; and
- application and service temperature.

Tapes are relatively easy to apply. The types that are commonly used are described below.

Polypropylene was developed for use in sealing seams of spun bonded olefin and polyethylene. This material may also be used on wood or on piping and ductwork that penetrates the air barrier or vapour barrier.

Foil-backed tapes are most commonly used to seal joints in foil-faced rigid insulations.

Metalized cloth tapes, commonly known as duct tapes, have been developed to prevent air leakage through the ductwork of forced-air heating systems. They are able to withstand high service temperatures.

5.2 LABOUR AND SUPERVISION

Whole house retrofit work generally requires minor modifications to conventional renovation work. When the contractor is aware of these changes prior to the start of work, the actual on-site work will flow more smoothly, with fewer costly mistakes and alterations. The knowledgeable contractor will be more ready to alter the construction processes to reflect regional labour availability and techniques and will be able to accurately price out the entire job. This will include

- proper sequencing of trades on the job site;
- easing the on-site work of trades by designing to accommodate specific trade practices;
- allowing all aspects of the job to proceed without interruption or delay; and
- avoiding duplication or alterations.

5.2.1 Skills Required for Whole House Retrofit

Only a few aspects of retrofit work will require additional instruction, training or site supervision. The experienced contractor will be able to transmit to the crews who perform the work the need for a quality job that will ensure effective insulation and air-tight construction.

Most retrofit work is performed by renovation contractors with relatively small-scale operations. While some use sub-contractors extensively throughout the course of their work, the large majority of renovators employ their own crews. In a typical operation, the contractor's crews would be responsible for

- wall preparation;
- wall framing;
- insulation; and
- installation of air barriers.

Sub-contractors are more likely to be called upon for

- siding;
- drywall;
- electrical work;
- plumbing work; and
- mechanical work.

The following checklist is designed as a guide to the contractor when outlining the requirements of any sub-contractor or crew performing work on major retrofit projects. These points might be included in job specifications for sub-contractors, or passed on to the contractor's employees as job guidelines. Where total retrofit work involves alterations to standard trade procedures the contractor should add to the specifications.

5.2.2 Exterior Retrofit - General Specifications

Preparation and Air Barrier Installation

- Any obstructions on the wall which might puncture the polyethylene are to be removed and/or relocated.
- Any projections causing large air pockets behind the polyethylene should be removed.
- Polyethylene is to be installed in the largest possible continuous sheets.
- Seaming techniques as discussed in Chapter 7 are to be employed.
- Any accidental rips or tears are to be repaired.
- Ladders and tools should not be leaned directly against the polyethylene.
- Polyethylene exposure to sunlight should be minimized or U.V. stabilized materials used.

Wall Framing

- Framing is to be installed plumb and level and shimmed as required.
- Framing centres must accommodate insulation and siding.
- The minimum required lumber is to be installed in order that thermal bridging be reduced, ensuring that adequate spans are met.
- Mechanical fastening of retrofit framing to the house must be directly to the studs, plates, or joists of the existing structure.

Insulation

- Insulation is to be installed so as to minimize air movement within the retrofit wall.
- Insulation should not be excessively compressed in the cavity.
- Insulation must be adequately protected from wetting and from long-term exposure to sunshine.

Sheathing/Siding:

- Wall sheathing should be installed in a manner which limits cold air circulation into the retrofit wall.
- Installation of an exterior air barrier will require taping of seams and joints over a solid backing.
- Flashing will be required above doors and windows.
- Downspouts will need to be relocated and reconnected.
- Flashing of sill extensions is recommended.

Electrical/Utilities

- The house electrical masthead and service entrance conduit may need to be relocated or temporarily held away from the exterior wall.
- Exterior outlets and lighting fixtures will need to be extended to the new outside surface.
- Gas lines/meters and oil tank fill pipes may have to be extended.

Plumbing

- Exterior hose bibs will need to be extended to the exterior of the new wall.

Vents

- The dryer vent and kitchen and bathroom exhaust fans will need to be extended.

5.2.3 Interior Retrofit - General Specifications

Preparation

- Before commencing new work, ensure that all structural defects are resolved.
- Any existing continuous air barrier or vapour barrier which might serve as a double vapour barrier should be punctured, torn or removed. For example, existing polyethylene vapour barrier in the wall, and/or finishes such as enamel paint, vinyl wallpaper and ceramic tile.
- Existing baseboards, window and door trim, etc. are to be removed.
- Where continuity of the retrofit wall between floors and partition walls is required, access to cavities must be allowed.

Framing

- A minimum amount of lumber is to be used for interior retrofit wall framing as the wall is non-load bearing.
- Ensure that adequate backing for interior finishes is provided.
- Rough framing of window extensions must allow adequate clearance for window lining.
- Framing must be designed to provide support or backing for baseboards, window trim and jamb extensions, electrical outlets and switches, etc.

Insulation

- Insulation is to be installed in a manner which limits convective air movement in the cavity. Excessive compression of insulation is to be avoided.
- Where continuity of the air barrier is restricted (i.e., joist cavities, partition wall top plates, etc.), rigid board insulation with low permeance is to be employed.

Air Barrier and Vapour Barrier

- The envelope is to be made airtight employing either a sheet or a rigid material.
- All seams and/or junctions of the material are to be taped, gasketed or caulked to restrict air movement.
- Any penetrations in the main air barrier are to be sealed with tape and/or caulking.
- The main air barrier is to be sealed and connected to window and door frames.
- Seams in the polyethylene air barrier are to be laid over a solid backing and are to be sandwiched by strapping and/or wallboard.

Interior Finishing

- Wallboard is to be pre-cut for electrical outlets and switches.
- Wallboard is to be marked for alignment of fasteners over studs or strapping.
- Baseboards and trim are to be nailed directly to blocking or studs.
- Electrical outlets and switches in the existing wall are to be relocated at the interior wall or removed; this may involve rewiring.
- Outlets and switches on exterior walls are to be sealed in air barrier boxes before being nailed to the studs.
- Penetrations of the air barrier are to be taped and sealed.

Plumbing

- Plumbing in the existing exterior house walls is to be relocated on the warm side of the wall.
- Plumbing stacks running into the attic are to be sealed with butyl gasketing or with a flexible collar.

5.2.4 Job Supervision

The contractor may want to spend more time with the workers until they have familiarized themselves with the new concepts and techniques used in retrofit work. The major 'new' component of total retrofit work relates to attaining a high level of air tightness. Whether using polyethylene or a structural material as the prime air barrier, continuity and a lack of accidental punctures are required to ensure good performance. Wherever possible, the supervisor should look for potential air leakage areas: tears, rips, badly seamed joints, etc., before these are covered.

Some contractors employ a technique for determining airtightness which has found a greater rate of acceptance in new house construction. A depressurization test involves installing a large exhaust fan into one of the house openings — usually a door. The fan induces a strong negative pressure (-50 Pa) which causes air to leak into the structure through the various leaks and cracks in the envelope. This test can cost between $100 and $150 and may therefore not be justified for each and every job. The depressurization test can, however, prove an extremely useful educational tool demonstrating the importance of good air barrier installation techniques to the workers on the site. Faults in the design and installation of the air barrier can be identified and improved installation practices can be developed. The exercise can also be useful for the contractor wishing to educate electrical, plumbing and drywall sub-contractors and it can serve as a valuable sales tool in discussions with the homeowner.

Trades Sequencing

Since some conventional trades sequencing may be altered, a clear job plan should be developed so that costly call-backs, wasted time, and duplicated effort are eliminated. The contractor will gain from the hands-on reaction of the crew and sub-trades to some of the scheduling difficulties. Most professionals are more than willing to share their views.

Some of the common problems which arise on the site of a major retrofit include the following:

- Electricians may need to perform preliminary work to the main house service – the masthead may need to be temporarily relocated to accommodate new framing.
- Remounting of electrical boxes on a new interior frame may interfere with conventional sequencing. Electrical outlets in the existing wall need to be extended to the new wall.
- Insulation work on externally applied retrofits will be highly weather dependent.
- Polyethylene installation for exterior work may be performed several days/weeks before the cavities are enclosed, leading to U.V. deterioration of the polyethylene.

5.2.5 *Job Costing*

The experienced contractor will realize that the total retrofit constitutes a small component of the total cost of either interior or exterior renovation work. Indeed, of the entire job, only a few aspects of the retrofit process will prove unfamiliar.

This manual makes no attempt to suggest specific costs for any given technique. Construction costs, for both materials and labour, vary according to location, availability and regional practices. Each contractor should determine costs based on local materials and labour costs.

For contractors with less experience in renovation, a list of the different issues affecting job costs for both interior and exterior work is provided.

The contractor quoting an exterior retrofit job will want to consider the following elements of the work:

- rectifying existing structural problems;
- relocation of electrical service connection;
- relocation or working around gas lines and meters, phone and television cables, hose bibs, etc;
- relocation of exterior lights, outlets, etc.;
- preparation of wall for air barrier;
- supply and installation of air barrier and sealants;
- labour and materials for wall framing or truss fabrication, installing insulation, and window extensions;
- labour and materials for wall sheathing or weather barrier;
- labour and materials for new siding/flashings; and
- site clean-up.

Costs associated with interior retrofit work will include

- rectifying existing structural problems;
- relocation or upgrading existing electrical and plumbing services;
- cost of any required demolition and disposal;
- labour and materials for wall framing and/or strapping, installing insulation, and air barrier installation;
- labour and materials for extending window sills and jambs;
- cost of providing air barrier around electric boxes;
- cost of patching into existing walls (plastering, paint); and
- cost of finishing materials and labour (baseboards, trim, painting, etc.).

5.2.6 *Health and Safety*

In retrofit work, potential risks exist for the health and safety of both the contractor/workers and the homeowner/occupant.

Proper construction practice can minimize these hazards. The risk of accidents can be reduced by:

- use of appropriate safety equipment for the task, such as hard hats, goggles, gloves, protective clothing and masks;
- use of appropriate equipment such as adequate ladders and scaffolding where required;
- maintaining equipment, such as electrical tools, in good repair with proper electrical grounds;
- following safety procedures when working around or near electrical and mechanical equipment;
- following general safety procedures when lifting, handling tools, materials and equipment, or working in awkward situations such as confined spaces or heights;
- maintaining a safe work environment with adequate lighting and secure, good footing; and
- following fire safety precautions around flammable materials.

Many excellent building products can have harmful effects on worker and occupant health if safety precautions are not followed. Always refer to detailed instructions provided by the manufacturer. Manufacturers' product spec sheets generally provide more detail on potential hazards and necessary precautions than product labels. For information on properties of sealants and potential hazards, refer to *Air Sealing Homes for Energy Conservation*. The CGSB publication, *Handbook on Insulating Homes for Energy Conservation 51-GP-42MP*, provides an overview of health and safety issues related to reinsulation as well as a description of potential hazards from various insulation materials. In summary the contractor should be aware of:

- noxious fumes and substances emitted by materials;
- irritants to the skin, the respiratory system, etc. caused by various products; and
- risks of long term exposure to products.

Advanced retrofit work will involve special circumstances not often encountered in new construction.

- Foundation trenches will be required for exterior basement retrofit. The trench walls should be properly shored and supported and the excavated material moved far enough from the trench edge to prevent an earth slide.
- The stability of the foundation wall should be assessed prior to exterior basement retrofit and appropriate measures such as shoring, taken to ensure stability during excavation.

- Scaffolding is recommended for exterior wall retrofits. This is not only a safer approach than the use of ladders but it allows easier access to the wall, saves on construction time, and avoids damage to the wall.
- Adequate scaffoldings will be required on roofs. Exterior retrofit most often involves the placement of polyethylene directly over the existing roof. Safe footing may be provided by placing wide plywood strips over the polyethylene and fastening through to the roof sheathing. Steep roofs will require scaffolding.
- In addition to hazards from new materials, interior retrofit may involve exposure to noxious substances from old materials that are being removed. These could include asbestos insulation around old hot water pipes, plaster dust, dust from lead-based paints etc. The contractor should be aware of potential hazards and maintain appropriate safety equipment on site.

BELOW GRADE RETROFIT

Heat loss through the basement of the average Canadian house can account for as much as 30% (or more) of the total fuel bill. The air sealing and insulation of basement walls is vital to the performance of any upgraded house.

Not only will below grade retrofit improve the energy performance of a house, but properly done it will turn a damp, cold, often musty environment into a comfortable living space.

This section provides an overview of basement retrofit for various foundation types and conditions. The suitability and techniques for both interior and exterior retrofit approaches are provided.

6.1 BUILDING SCIENCE CONSIDERATIONS

Like other parts of the house envelope, basements lose heat by conduction, convection (air leakage) and radiation. The total retrofit will address conductive losses through the walls by adding insulation. In addition, the retrofit should address the many sources of air leakage:

- through cracks in concrete or masonry;
- through service penetrations (electrical fuel, exhaust and intake vents;
- around window frames; and
- at the sill plate and floor joists.

The choice of whether to retrofit the basement from the interior or exterior, and what techniques to use will be influenced by a number of considerations. These include

- the type of existing foundation;
- the type of soil and frost conditions;
- accessibility;
- moisture movement; and
- the characteristics of water movement around the foundation.

Type of Existing Foundation

Older basement walls of rubble or brick were usually built without dampproofing and are more subject to moisture movement. Whether the retrofit is interior or exterior, moisture will still be able to enter these walls at the footings and wick upwards (Figure 6.1).

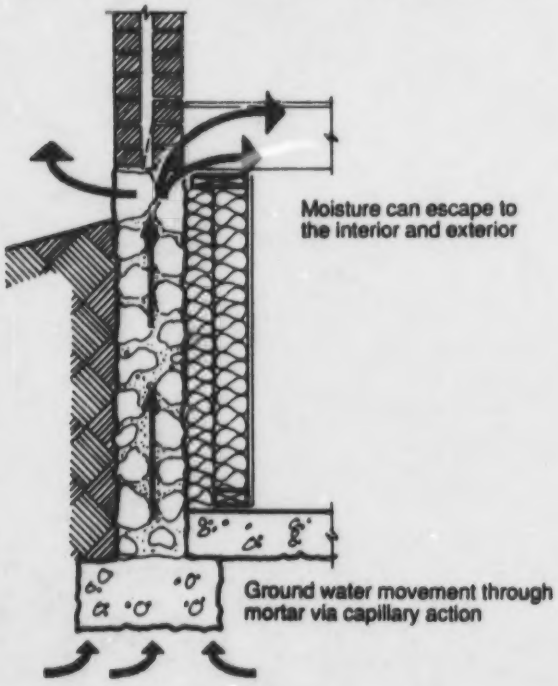


Fig. 6.1 Moisture movement in older foundations

In order to avoid damage to materials, it is necessary to provide an escape route for this moisture at the top of the wall.
Basements and crawl spaces with earth floors will require separate moisture-proofing measures.

Type of Soil and Frost Conditions

Fine grained soils such as silt or clay are subject to frost heaving when water is present. Reduced heat loss through the foundation wall can result in lower soil temperatures, greater depth of frost penetration and an increased potential for frost heaving, although the actual incidence of foundation failure due to insulation is extremely rare in Canada. An exterior retrofit provides greater protection for the wall and offers the opportunity to replace the perimeter soil with granular fill which is not as susceptible

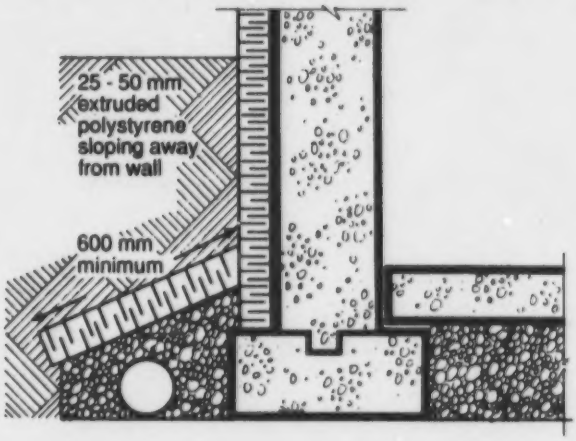


Fig. 6.2 Skirt insulation for shallow footing

to frost heaving. Shallow footings can be protected from frost by placing insulation horizontally around the footing (Figure 6.2).

Accessibility

Access to the foundation wall may prove a major factor in deciding whether to insulate on the inside or outside. In urban areas, small lot line setbacks, porches, driveways, etc., may cause problems to the excavator. Interior retrofit work should consider plumbing, ducting, electrical and laundry facilities which may prove costly to relocate or work around.

Moisture Movement

Moisture readily moves from the soil through some foundation materials (mortar in unit masonry walls, rubble or brick foundations) (Figure 6.3). Where an interior retrofit is undertaken, the insulation materials must be protected from moisture by a dampproofing material applied to grade level. An exterior retrofit with dampproofing effectively blocks the entry of moisture from the soil through the wall.

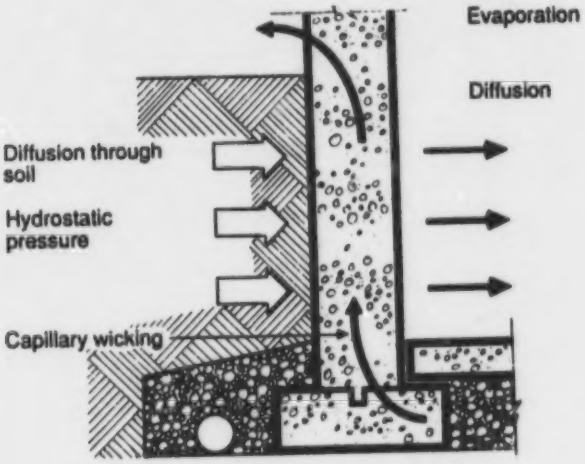


Fig. 6.3 Moisture movement

Water Movement

Where water penetration through basement walls is a common occurrence, an exterior retrofit is appropriate. As well as upgrading energy performance, the project can include remedial measures to overcome leakage problems such as:

- application of a dampproofing membrane (a bituminous coating or sheet polyethylene) to the outside of the wall (Figure 6.4);
- installation of a perimeter drainage tile and self-draining insulation (rigid glass fibre) which can overcome the need for a waterproofing membrane; and
- proper sloping of soil away from the foundation.

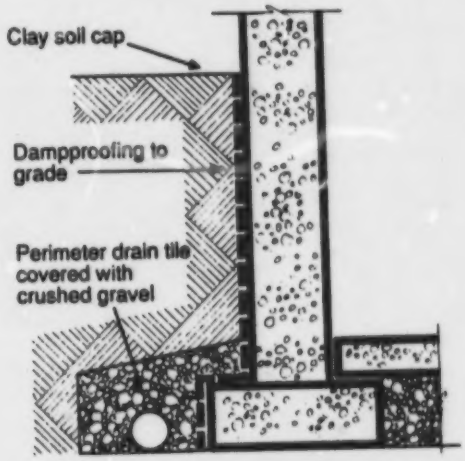


Fig. 6.4 Proper drainage procedures

6.2 EXTERIOR BASEMENT RETROFIT

Externally applied basement retrofit work is most easily justified as part of ongoing house renovation or home improvement work. When a house wall needs to be exposed to eliminate water problems, insulation can be added easily and cost-effectively.

The following overview of external insulation options will provide a brief synopsis, highlighting design and construction considerations. For a more complete discussion, refer to *Insulating Basements, Crawl Spaces and Slabs-on-Grade* as listed in Appendix B. The following issues must be taken into account when planning the work:

- Site Preparation;
- Insulation Options;
- Fastening Techniques;
- Above Grade Protection;
- Supervisory Requirements; and
- Job Costing.

6.2.1 Site Preparation

Excavation around the foundation wall can be done by backhoe or by hand, depending on space available. Consideration should be given to the protection of the surrounding grass/surface. Placing excavated material onto a tarp can ease clean-up.

Before excavating, all service lines (water, sewer, hydro, gas, oil, telephone cable, etc.) should be located and marked.

Where perimeter drainage tile is damaged or non-existent, a new perimeter drainage system should be installed.

If the foundation has been leaking, a new parging coat and dampproofing material should be installed before insulating. Alternatively, a layer of 0.15 mm polyethylene can be installed over the wall and sealed at the top, or a draining insulation material can be employed.

6.2.2 Insulation Options

The major options for exterior foundation insulation include rigid boards made from either polystyrene, polyisocyanurate, polyurethane or glass or mineral fibres. The advantages and disadvantages of the different materials are presented in 5.1.2.

6.2.3 Fastening Techniques

A variety of materials and systems have been designed to fasten rigid board insulations to masonry surfaces. While soil pressures are usually adequate in securing the insulation below grade, above-grade fasteners are needed to hold both the insulation and the protective coating in place. Depending on the amount of insulation being installed, the fasteners will range from 75 mm to 125 mm in length. They can be anchored to the masonry in pre-drilled holes or they can be installed with a nail gun. The nails or bolts are installed through washers or channelling systems which hold the insulation and/or protective coating in place. Consult the manufacturer's specifications for proper fastener depth and spacing.

6.2.4 Above Grade Protection

Externally insulated foundations will require a protective coating above grade to protect the insulation from accidental damage and from weather. The choice of material used to cover the insulation will be dictated by aesthetic preference, installed cost, and durability of the material. While regional preferences exist, the main options for covering the insulation include

- expanded metal lath and parging;
- metal siding;
- fibre reinforced concretes or proprietary coating systems; and
- pressure treated plywood.

The protective coating should extend at least 300 mm below the line of the finished grade.

Rain, ice and snow must be prevented from getting between the insulation and the foundation wall. Insulation which extends above grade must be flashed with either pre-painted metal, plastic, or pressure treated wood flashing and caulked to ensure positive drainage away from the wall. (Figures 6.5, 6.6 , 6.7).

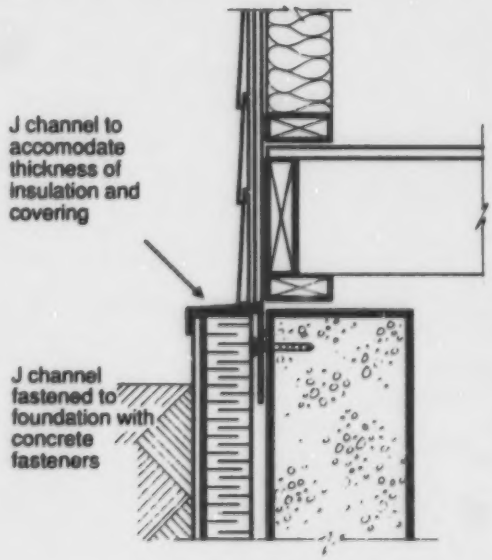

J channel to accomodate thickness of insulation and covering
J channel fastened to foundation with concrete fasteners

Fig. 6.5 J channel flashing

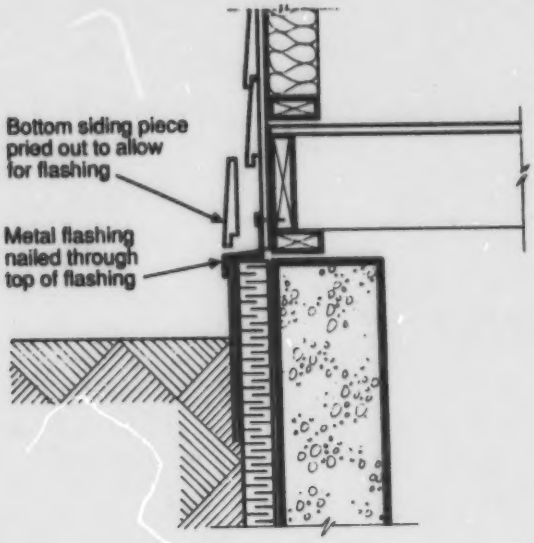


Fig. 6.6 Metal flashing

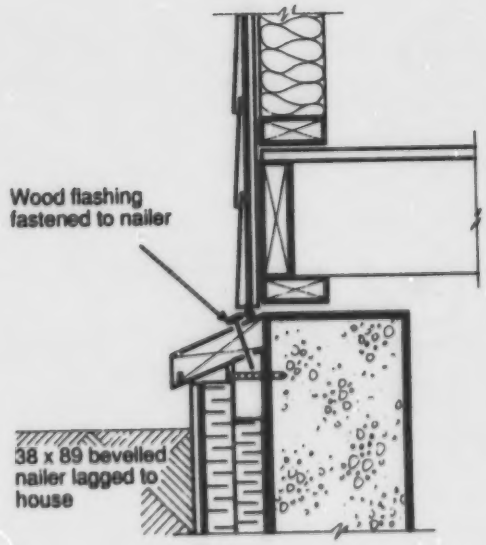


Fig. 6.7 Wood flashing

Additional flashing and finishing work will be required where penetrations exist in the foundation wall. Openings such as windows and doors will need to be finished in a manner which promotes drainage and reduces weathering problems. (Figure 6.8)

Where the basement window extends below grade, such as with a window well, the retrofit may allow for improving drainage in that location.

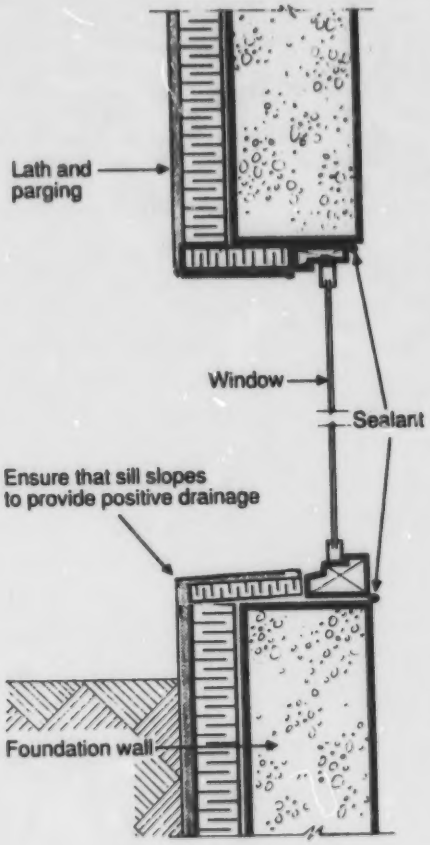


Fig. 6.8 Finishing detail around windows

Supervisor's Checklist

The following checklist can be used by a job supervisor to ensure that potential problem areas are double-checked. While the list serves as an outline of the various steps of the job, the supervisor should perform a visual inspection before proceeding to the next phase of the work.

- excavation materials removed and stored to prevent damage;
- services undamaged and reconnected as necessary;
- drain tile properly connected;
- dampproofing properly installed;
- gaps in insulation filled;
- corner beading installed over lath where applicable;
- adequate mechanical fasteners provided for above-grade protection;
- above-grade flashing made weathertight;
- adequate slope of sills provided at windows and doors; and
- adequate slope of finished grade provided.

6.3 INTERIOR BASEMENT RETROFIT

Interior retrofit work can most easily be justified as part of ongoing renovation or home improvement jobs. When the basement is being renovated, insulation can be installed easily and cost effectively. The following provides a brief synopsis, highlighting the various design and construction considerations. For a more complete discussion, refer to *Insulating Basements, Crawl Spaces and Slabs-on-Grade* listed in Appendix B.

Issues that must be accounted for when planning the work include

- Site Preparation;
- Dampproofing Options;
- Insulation Options;
- Framing/Fastening Techniques;
- Air Barrier Requirements;
- Sill/Header;
- Supervisory Requirements; and
- Job Costing.

6.3.1 Site Preparation

Performing retrofit work on the basement interior can involve a considerable amount of preparatory work. As discussed in Section 6.1, the contractor will want to assess the existing foundation wall for any deterioration or indication of moisture problems. Major problems must be fixed – generally, this is best done from the outside of the foundation.

The ideal basement for interior retrofit should be empty, featureless and all services (electrical, plumbing, HVAC) should be near the centre of the basement. This allows the installation of insulation without time being lost in relocating ductwork, plumbing lines and fixtures and electrical outlets. Unfortunately, most basements will have many obstacles. Among other issues, the contractor will need to evaluate the costs and benefits of moving obstacles such as:

- heating ductwork or piping;
- service inlets for oil, gas, or electrical services;
- plumbing lines and fixtures;
- oil and DHW tanks;
- house wiring and outlets; and
- built-in storage and work tables.

A moisture barrier should be installed over the existing foundation wall - especially when using batt insulation or other moisture absorbing materials. **The moisture barrier should extend from the floor slab to grade level** (Figure 6.9). The moisture barrier will restrict water vapour diffusion from the foundation wall. The moisture barrier material most commonly used is sheet polyethylene, although building paper and plastic insulation (25 mm) can also be used.

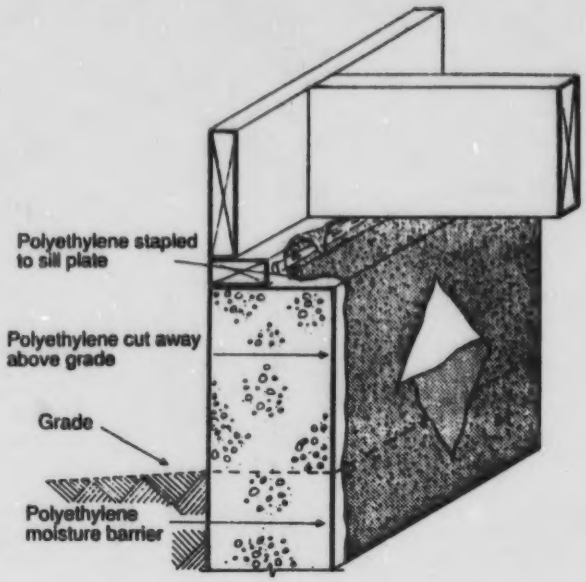


Fig. 6.9 Dampproofing to grade

6.3.2 Insulation Options

Rigid board insulations can be installed on the interior of the foundation wall. They come in a variety of material types with different fastening techniques. Rigid boards are recommended only where the foundation wall is relatively flat and plumb so that convective loops between the insulation and the wall are minimized. The major material options include

- expanded polystyrene (Type I , II);
- extruded polystyrene (Type III, IV);
- polyurethane or polyisocyanurate; and
- rigid glass fibre board.

Advantages and disadvantages for each material are discussed in Chapter 5.

Batt insulation, either glass or mineral fibre, can be installed as an effective, low-cost insulation technique. The batts can be housed by a variety of means, but most typically, a new frame wall would be erected to support the insulation and to provide a nailing base for the wallboard. Batt insulation can be installed in either one step or as a two-step (horizontally and vertically) process. The use of the two-step process will minimize thermal bridging across the frame and will reduce the potential for convective air movement between batts (Figure 6.10).

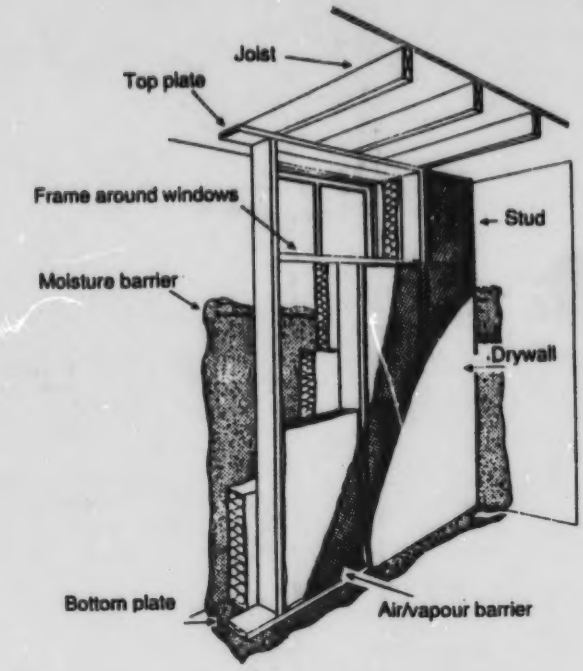


Fig. 6.10 Interior retrofit

6.3.3 Fastening/Framing Techniques

A variety of fastening techniques is available for the application of rigid board insulations to foundation walls. The choice as to which options to use should be based on cost and availability of the system and ease of application. Rigid boards can be fastened with different proprietary channeling systems or with various strapping techniques using conventional lumber or metal studs.

Channeling systems are available in many different configurations as illustrated in Figure 6.11.

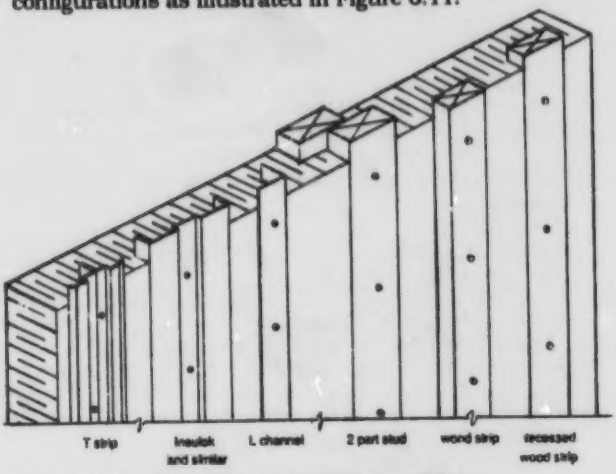


Fig. 6.11 Mechanical fastening options

The channels are usually fastened to the masonry at 600 mm centres using either galvanized concrete nails or bolts. The fasteners can be installed with a nail gun or lagged or nailed into pre-drilled holes, to a minimum depth of 25 mm.

Wood strapping can be employed as a fastener in two different manners. The insulation can be installed between strapping layers or the strapping can be installed over top of a rigid board insulation. In both cases, the later installation of wall board is simplified as it can be fastened directly to the strapping. To facilitate the installation of wiring and outlets, a chase can be provided by installing a 38 x 38 mm strapping (Figure 6.12).

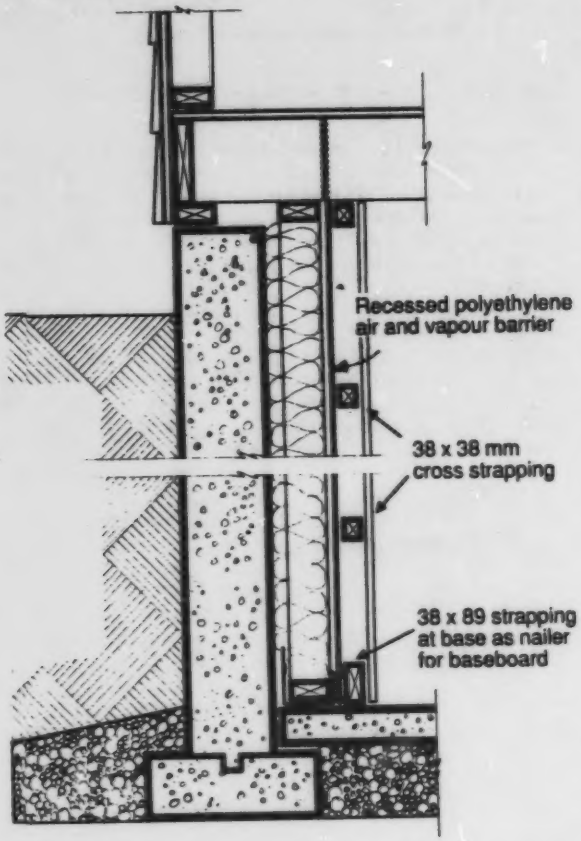

Recessed polyethylene air and vapour barrier
38 x 38 mm cross strapping
38 x 89 strapping at base as nailer for baseboard

Fig. 6.12 Cross strapping

Framing of new insulated walls for house basements must account for the following issues.

- All wood in direct contact with concrete or masonry in contact with the ground, must be either presssure treated wood or separated from the concrete by a layer of polyethylene or polystyrene (Figure 6.13). This prevents water from wicking from the concrete into the wood.

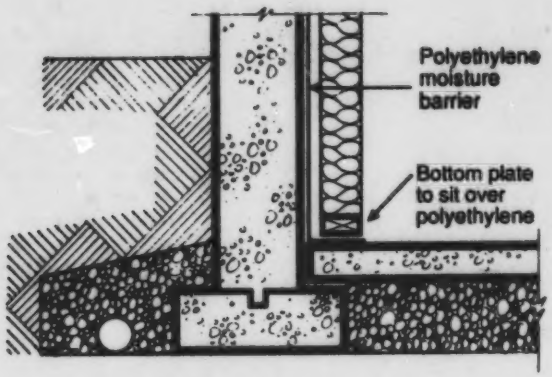


Fig. 6.13 Avoiding wood/concrete contact

- The framing lumber can be of a smaller dimension than might conventionally be employed. Since there is no structural loading on the wall, 38x64 mm can be used for the framing, spaced at 600 mm on centre. Closer spacing of the studs may be needed where slight deflections in the pannelling or wood are not acceptable.

- The distance which the framing is located from the existing wall should be determined by the amount of insulation required. The incorporation of RSI 3.5 would demand that the frame be located 140 mm from the wall, allowing for the combined installation of RSI 2.1 and RSI 1.4. (Figure 6.14).

6.3.4 *Air Barrier and Vapour Barrier Requirements*

An effective air barrier and vapour barrier is important to the overall performance of a newly insulated foundation wall. Three different approaches can be followed:

- installation of continuous polyethylene sheets;
- sealing of low permeance rigid board insulations; and
- installation of structural air barrier and separate vapour barrier.

Installation of polyethylene sheets as outlined in Chapter 5 can provide an effective combined air barrier and vapour barrier. Proper sealing of seams, penetrations and junctions with other materials is required to ensure a good air seal. This is generally the easiest method to provide an air barrier.

Low permeability rigid board insulations can be caulked at the seams, or sealed with various vinyl or foil-faced, adhesive-backed tapes. The caulks or tapes must be compatible with the materials employed as specified by the manufacturer.

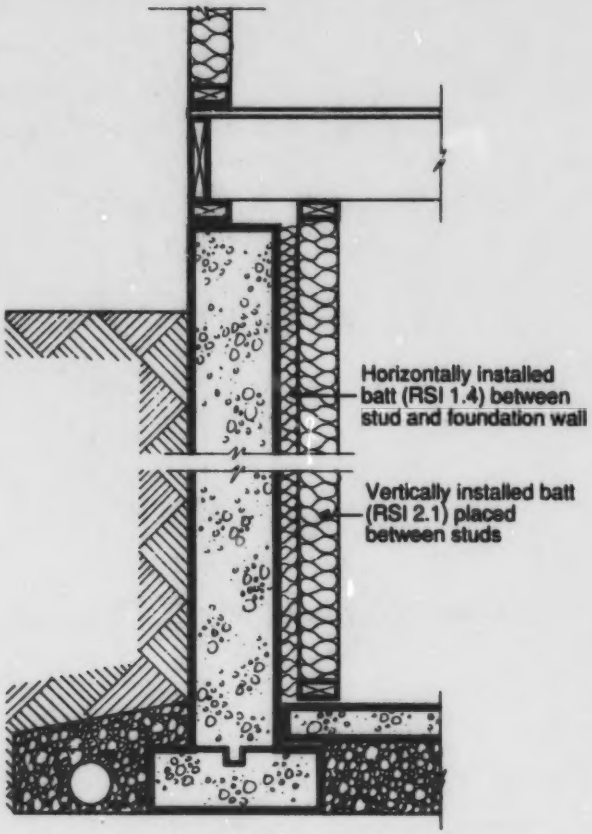

Horizontally installed batt (RSI 1.4) between stud and foundation wall
Vertically installed batt (RSI 2.1) placed between studs

Fig. 6.14 Installing Insulation

Structural materials can provide an effective air seal when they are used as the air barrier as outlined in Chapter 5. They must be supplemented with a separate vapour barrier such as polyethylene, vapour barrier paints, foil backing, etc.

6.3.5 *Sill/Floor Header Detailing*

Air barrier requirements and insulation techniques at the sill and floor joists will vary depending on the material and construction of the foundation wall, and may require a combination of techniques.

Poured concrete and concrete block foundations

For these types of foundations, the detailing is relatively straightforward.

- The wall insulation and the main air barrier are brought to the underside of the joists and a flange is provided on the air barrier. The joist area is insulated and an air barrier and vapour barrier installed. A fire-rated protective covering must be provided over some materials.

a) One option involves using a glass fibre insulation product that is packaged in specialty plastic bags sized to fit standard joist spacings. The bags are pressed into place and sealed to the main air barrier (Figure 6.15).

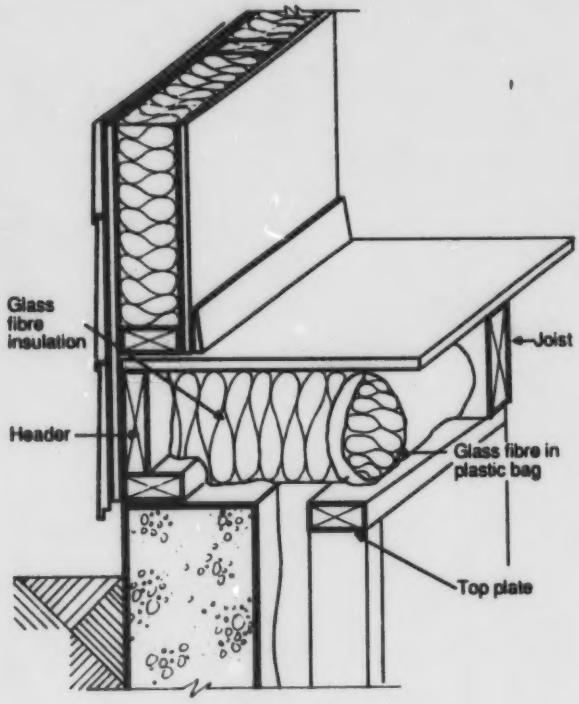


Fig. 6.15 Insulating joist cavities

b) Alternately, low permeance rigid or semi-rigid board insulation may be cut to fit the joist spaces and caulked to the joists, the underside of the sub-floor and the flange on the main air /vapour barrier (Figure 6.16).

c) Spray-on urethane may be applied, either over batt insulation, to be flush with the top plate of the wall, or directly onto the header area.

- The flange of the main air barrier is sealed to the material between the joists.

Rubble or brick foundations, OR foundations with joists framed directly into masonry

It is preferable to insulate these types of walls from the exterior. This is because water vapour moving through the foundation wall will start to condense at the joist ends if they are kept cold because of interior insulation. If water vapour cannot escape to the inside because the path is blocked, the moisture will migrate further up the wall and possibly to the outside. There it can cause damage to the exterior.

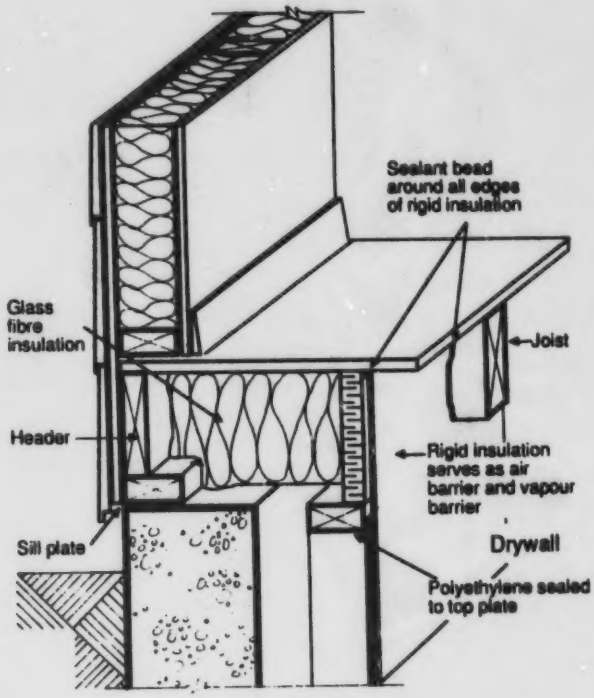


Fig. 6.16 Insulating joist cavities

Where an interior retrofit is chosen, it is advisable to
- leave the joist space uninsulated;
- avoid concealing the joist ends behind an air barrier/vapour barrier; and
- refrain from painting or covering the joists and sill plate.

The recommended strategy involves reducing air leakage through the joist space by:

- caulking at the junction of sill plate or masonry to joists; and
- caulking at the junction of the joists to the header (Figure 6.17).

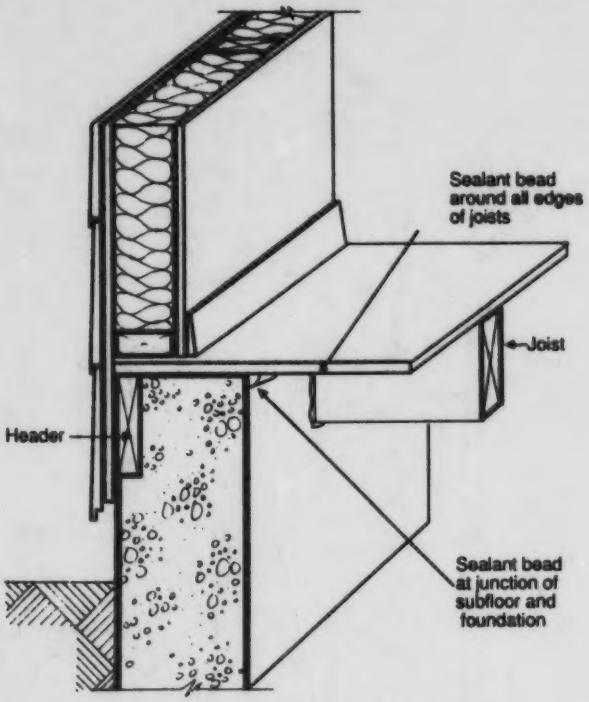


Fig. 6.17 Sealing joist cavities

Supervisor's Checklist

The following checklist can be used by a job supervisor to ensure that those aspects of the job requiring special attention are double-checked.

- services relocated and reconnected as necessary;
- moisture barrier installed to level of outside grade;
- wood members not in direct contact with concrete;
- air pockets behind insulation minimized or eliminated; and
- air sealing effectively installed at junctions and around penetrations.

EXTERNALLY-APPLIED ABOVE GRADE RETROFIT

Chapter 4 of this manual provides an overview of above grade externally applied retrofit work. While this retrofit approach should result in significant energy savings and improvements in comfort, it can be limited by aesthetic concerns, lot line setback restrictions and relatively high costs. It should be stressed that exterior retrofit work is most easily justified as part of already planned work on the house exterior such as residing. The various benefits and limitations, as detailed in Chapter 4, should be considered with the homeowner.

7.1 DESIGN AND CONSTRUCTION GUIDELINES

This section of the manual examines the design and construction issues affecting exterior above-grade retrofit. Five specific exterior retrofit systems are presented in section 7.2 with detailed system techniques and considerations. While each of the systems outlined has its own limitations and strengths, several issues must be addressed which will relate to every exterior retrofit. While framing or strapping techniques will alter according to the contractor's preferences, several construction steps will need to be performed on all systems.

The major steps of an effective exterior retrofit as illustrated in Figure 7.1 include

- Wall preparation;
- Installation of an air barrier and vapour barrier;
- Framing or strapping of the new retrofit wall;
- Insulating the retrofit wall; and
- Sheathing and siding.

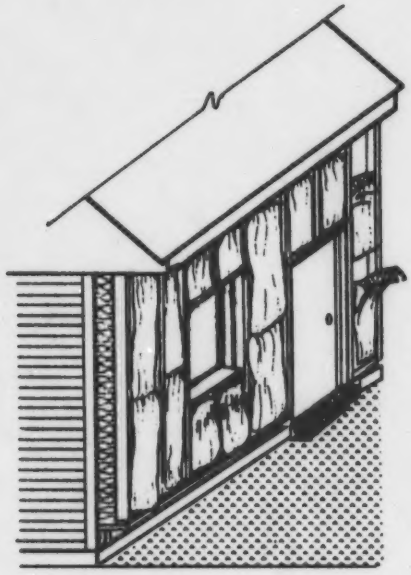


Fig. 7.1 Exterior Retrofitting

The following sections provide design and construction highlights for the different stages of the exterior retrofit. Those principles and theories explained in Chapter 2 of this manual are highlighted in the following text – specifically as they relate to the design and construction of an effective retrofit.

7.1.1 Wall Preparation

- The wall should be inspected for the work that is required. Is there access to the site? Is there enough space to work or erect any required scaffolding? Are there any bushes or prized flowers that should be moved?
- Any penetrations or obstructions in the existing house walls should be dealt with. The obstructions may have to be temporarily removed, and later installed onto the new wall. Penetrations and obstacles that require removal or extension include downspouts, outdoor taps, outdoor lights and outlets, and venting ducts from kitchens, bathroom and clothes dryers. **When electrical mastheads and meters and natural gas lines and meters must be moved out to accommodate the new wall, a licenced tradesperson must be employed.**
- Assess the condition of the siding. If it can be re-used on this or another job, then carefully remove it. When planning to re-use the siding on the house, remember that the new wall will be wider than the old wall and extra material may be required. Enlarged corner boards can reduce the need for extra siding. The old siding should be removed if it is badly deteriorated or rotted.
- Many older houses have serious structural problems due to rotting studs and beams. If it is suspected that this is possible, remove a section of siding to determine the condition of the house. The most logical place to look for trouble is at walls near the kitchen and bathrooms, where high moisture levels may be experienced. Any problems should be corrected since the new wall will add to the load on the house.
- Consider any features that might cause a puncture or tear in the polyethylene air/vapour barrier. For example, rough stucco might have to be removed first or, more practically, covered with a layer of building paper. Sharp corners should be softened.
- Consider the design of the retrofit wall. Ensure that there is a flat surface to affix the retrofit wall – often at the bottom and top for a ledger plate, and at the mid-section for multi-storey walls (Figure 7.2).

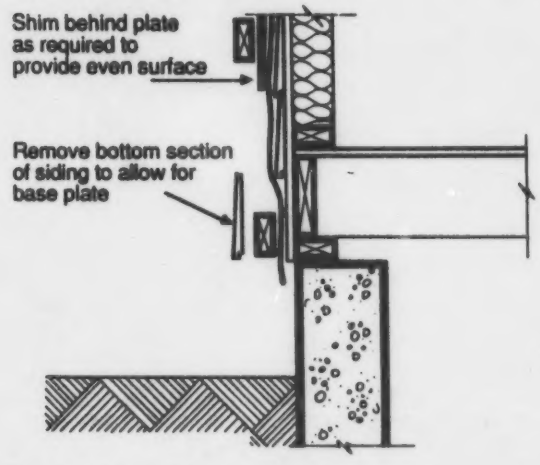


Fig. 7.2 Providing a level surface

7.1.2 Air-Vapour Barrier Installation

- A continuous air barrier is wanted throughout the building envelope. All seams and edges are sealed, as are any penetrations through the air barrier. If at all possible, the air barrier should extend from the building top plate to below the first floor joists and sill, and be sealed to the foundation. Ideally, it should continue down to the footings as part of an exterior foundation retrofit.

- Either polyethylene or a spunbonded olefin (Tyvek) could be used as the air barrier. In general the use of polyethylene will prove more economical. Consideration must be given to the placement of the polyethylene, ensuring that the 1/3 - 2/3 rule (as dicussed in Section 7.1.3) is followed.

- Large sheets should be used to minimize the number of seams that have to be sealed.

- When installing sheet air barriers, all seams should overlap at least 150 mm and should be mechanically sandwiched between two solid surfaces. A continuous bead of non-hardening sealant, such as acoustical sealant, is run between sheets (or over the siding at the edge). The top sheet is pressed lightly over the bead and staples are affixed through the bead every 150 mm. **The seal is completed when a solid member is nailed over the seam.** Alternatively, specialty air barrier tapes can be employed, although the cost will be much greater. This last step, mechanically fastening the seam, is critical to ensure a long life to the seal (Figure 7.3).

- The air barrier should be sealed around any penetrations such as venting, plumbing and piping, and around any electrical fixtures and outlets. The air barrier must also be sealed directly to window and door jambs or to the brickmould to ensure airtightness. Detailed window installation techniques are discussed in Chapter 9.

- The polyethylene should be carefully inspected before it is covered with insulation and siding. To minimize damage during construction, ladders, materials and tools should not be stood against the polyethylene. All holes, tears or weak seams should be marked and repaired. Small holes can be patched with different tapes. Large holes should be patched with a large piece of caulked or taped polyethylene.

- Installation of the polyethylene can be made easier if it is hung from the top and then secured.

Other tips for installation of polyethylene include the following:

- Do not stretch the polyethylene during installation. It doesn't seal any better and there is a greater chance that the seam will fail. Polyethylene contracts as it gets colder.

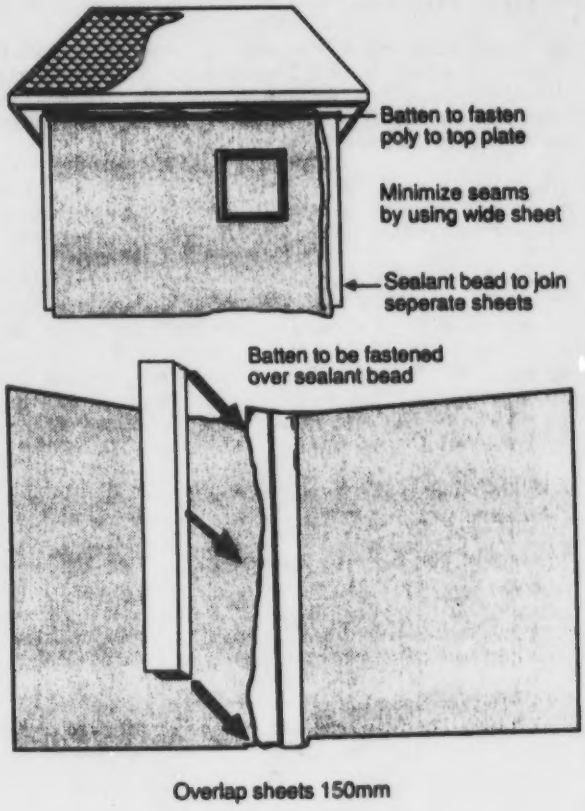

Batten to fasten poly to top plate
Minimize seams by using wide sheet
Sealant bead to join seperate sheets
Batten to be fastened over sealant bead
Overlap sheets 150mm

Fig. 7.3 Installing sheet air barrier

- Minimize the number of staples used to hold the sheets up. Each unnecessary staple means a potential hole in the air barrier.

- Do not block the soffit ventilation. Similarly, don't block any deliberate vents or openings, but ensure that there is a good seal around the penetration.

- Always leave extra material, about 150 mm, on any overlaps.

- Do not leave any polyethylene materials exposed to the sun for long periods. If this is necessary, then use carbon black or UV-stabilized polyethylene (see the discussion in Materials). Alternatively, some framing systems will allow the sheets to be installed after the framing is erected, but before it is completely tied to the house. This will minimize the time the material is exposed.

- Do not install on a windy day.

7.1.3 *Framing*

Exterior retrofit work can employ framing with batt insulation or rigid board insulation. The measures discussed in this section relate to framed or strapped retrofit systems. Rigid board installation techniques are presented in Section 7.2.5.

The purpose of the framing in an exterior retrofit is to provide a cavity for the insulation and a nailing support for the new siding.

A cavity for insulation can be made in any thickness depending on the ledger plate or truss system used. Typically, the new wall is erected to allow for standard glass fibre batts. A space of 140 mm will accept RSI 3.5 batts, while a space of 190 mm will accept RSI 4.9 batts. Higher or lower insulation values can be built in as long as the following aspects are considered:

- The framing assembly is structurally sound.
- At least two times the insulating value of the old wall assembly is on the cold outside of the new air barrier/vapour barrier (see Section 2.5.4). This rule of thumb, called the 1/3 - 2/3 rule, will work for most Canadian locations. For extreme northern locations (above 7000 DD), the vapour barrier should be located closer to the house interior.
- The design minimizes thermal bridging and convection currents.
- The insulation value used can be rationalized. Too much insulation will provide a poor return on the investment while too little will not make the work worthwhile.

The new wall must be able to withstand the loadings imposed by winds, snow loads, dead loads of the framing, insulation, siding and in some cases, windows and doors. The important areas are the base detail, the soffit detail and detailing around windows and doors (Figure 7.4).

There are several variations in base detail and some systems, such as truss walls, do not use a structural ledger plate. Whatever base detail is used, the mechanical fastening of the support plates must be strong. In most cases, lag bolts should be used as fasteners. They should be sunk into part of the main house structure, either to the studs, joist header or solid brick — not into siding, sheathing or brick veneer.

The wall can be supported back to the house using a medium-gauge galvanized plumber's strap fastened either to the ledger plate or to the individual studs. A strap connected to every other stud can support 1000 kg of dead loading – easily adequate for two storeys.

Some systems hang from the house rafter tails. Under extreme circumstances, an excessively heavy load at this point could force a hinging action in the house roof. To offset this potential problem, several alternative mechanisms should be used to displace some of the dead load. This might involve transferring some of the loading to the wall studs or the joist header (Figure 7.5).

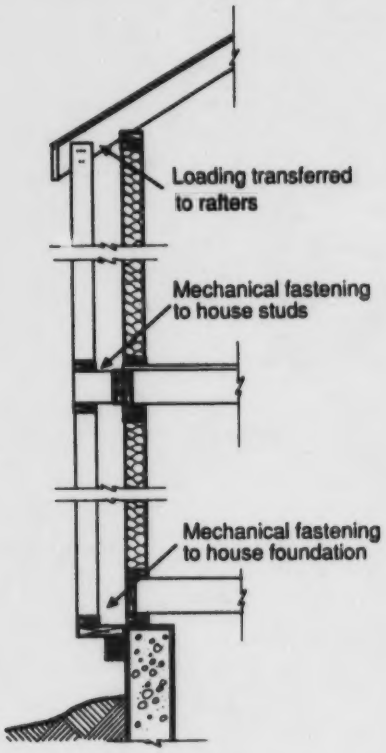


Fig. 7.4 Transferring loading to the house

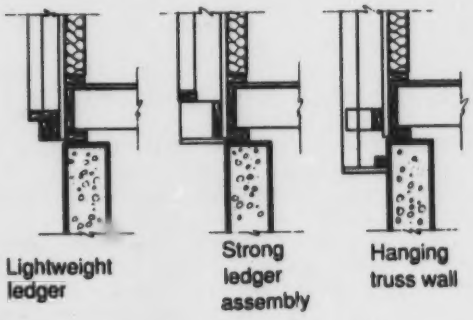


Fig. 7.5 Supporting base assemblies

A secondary concern is the differential shrinkage of wood; specifically, the differential shrinkage between cross grain versus parallel grain lumber. Under extreme conditions, this could cause a differential movement between the old wall and the new curtain wall. The results could be bent flashing and cracks in caulking around windows and doors. In most cases the house will have already reached a state of equilibrium and will remain stable.

Keeping in mind the concerns of structural integrity, a curtain wall should be built that minimizes the amount and dimensions of lumber. Typically, a 190 mm ledger plate will support a frame wall that is made from 38 x 64 mm studs which are set away from the old wall at the outer edge of the ledger plate. The studs can be spaced 600 mm o.c. depending on siding requirements. If the ledger plate is continuous, a single 19 x 64 mm top and bottom plate can be used. Using these framing dimensions can minimize lumber and, therefore, materials cost and labour. It can also provide a more energy-efficient wall. Less lumber means more insulation.

Framing around windows and doors should allow for the new trim and a new sloping sill.

Any wood in the framing that will end up being within 200 mm of grade must be treated or preserved wood.

7.1.4 *Insulation*

Following good construction practices, the insulation is carefully installed. Where possible, it is installed in two layers; the first layer horizontally behind the studs, the second layer vertically between the studs. Care is taken at edges and corners to minimize gaps in the insulation that can allow convection currents.

If a truss system is used, rigid insulation can be installed between the chords of each truss before the batt insulation is placed between the trusses, or extra wide batts will be required.

It should be remembered that immediately before insulating, there should be a final inspection of the air barrier.

7.1.5 *Sheathing/Siding*

Once insulated, the wall can be finished with sheathing paper and siding as in conventional construction, depending on the cladding technique. Sheathing can be added if, for example, the wall is to be stuccoed, or requires additional racking support. Sheathing paper is required beneath the siding – two layers if there is no sheathing board. Many contractors are now using spunbonded olefin sheet material. This provides an effective air barrier on the exterior while allowing water vapour to pass through. The seams and edges of the sheets should be taped. Only one layer of taped spunbonded olefin is required. The sheets are available in 2700 mm widths to cover one full storey.

Siding options are similar to conventional building.

- Horizontal siding can be nailed directly onto the new studs.
- Vertical siding, such as board and batten, will require horizontal strapping 600 mm o.c. to provide nailing support.
- Stucco will require rigid sheathing with an expanded metal lathe.
- Brick veneer siding is more difficult to install with a curtain wall because of the extra loading. It may require the installation of a supporting foundation wall extending to the footings or the installation of angle iron.

Some siding materials will deflect or twist when installed on wide stud centres. Hardboard siding should be installed on stud spacings no greater than 400 mm o.c. Metal and vinyl siding requires a sheathed backing on the wall. Vinyl and hardboard siding must be allowed to expand and contract. Nailing should allow the siding to move; nail in the centre of the nailing slots.

Proper siding techniques will include

- squaring or levelling of the starter strip/siding;
- provision of flashings above windows and doors;
- ues of siding which should be at least 200 mm above finished grade;
- use of corrosion-resistant fasteners; and
- use of fasteners which should penetrate a minimum of 25 mm into solid wood.

7.1.6 *Extending the Retrofit*

It is sometimes desired to extend the exterior retrofit either up past the soffit and over the roof or else below the base plate all the way to the footings. Similar principles apply in either case, including the requirements and positioning of an air barrier/vapour barrier. However, a poured concrete basement wall may serve as an effective air barrier if it has not developed cracks.

Continuing Below-Grade Extending the exterior insulation over the foundation to the footings is covered in detail in Chapter 6 and in *Insulating Basements, Crawl Spaces and Slabs-on-Grade.* Combining basement insulation with an exterior wall retrofit involves

- extending the air barrier/vapour barrier continuously past the ledger plate partway or all the way to the footings;
- insulating with a rigid or semi-rigid board;
- ensuring that the insulation covers the ledger plate where possible (see diagram) to reduce the thermal bridging and conform to the 1/3 – 2/3 rule of vapour barrier placement;
- providing protection for above-grade insulation to the wall plate; and
- installing proper flashing at the junction of the above-grade and below-grade materials (Figure 7.6).

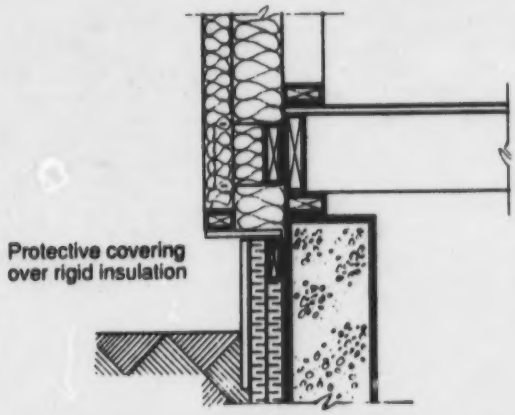


Fig. 7.6 Continuing the retrofit below grade

Going Up (and Over) Extending the exterior insulation over the roof is done under some circumstances, as covered in Chapter 10. As illustrated in Figure 7.7, combining this with an exterior wall retrofit involves

- extending the air /vapour barrier continuously past the soffit to the roof – this may require cutting back the original roof rafters;
- extending the curtain wall up past the original rafter to the position of the new roof rafters;
- considering fastening of the new curtain wall if it is carrying the dead load of the new roof;
- ensuring that new soffit ventilation is provided for the new roof;
- ensuring that insulation over the extended air/vapour barrier is at least twice the insulation value of insulation on the inside; and
- ensuring that the structural adequacy of the old roof is initially assessed.

Fig. 7.7 Extending the retrofit over the roof

7.2 EXTERIOR INSULATION OPTIONS

Chapters 3 and 4 identify the various evaluation and decision-making criteria which will guide the contractor and homeowner through the retrofit process. The following worksheets provide detailed instructions and guidance on the actual construction process. The worksheets are presented in a manner which outlines an entire system, highlighting a preferred approach to the design and construction of the wall retrofit. Variations to the overall theme are presented where required.

It is assumed that the individual contractor will consider and develop alternative approaches to these systems which reflect regional material and labour preferences. Design flexibility and contractor initiative are encouraged, providing that the basic concerns and considerations relating to good envelope design are followed.

The details incorporated throughout the manual assume that the contractor follows good building practices. No specific details relating to interior finishing or exterior siding installation have been included. Similarly, basic construction techniques such as nailing patterns, framing techniques, etc., have not been detailed. For those readers who are not professionally involved in construction, *Canadian Wood Frame Construction*, published by Canada Mortgage and Housing Corporation, and *Canadian Wood Construction Datafiles*, available through the Canadian Wood Council, provide a good fundamental background to construction techniques.

The following options for insulating from the outside are detailed:

7.2.1 Curtain Wall Supported by Perimeter Base Assembly
7.2.2 Truss Wall Fastened to House Studs
7.2.3 Strapped Wall
7.2.4 Curtain Wall Supported at Rafter Tails
7.2.5 Rigid Board Insulation

Several of the above systems may be combined to handle particular problems on the house.

7.2.1 *Curtain Wall Supported by Perimeter Base Assembly (Figure 7.8)*

This exterior retrofit strategy involves the installation of a supporting base assembly around the perimeter of the building after the air barrier or air/vapour barrier is installed. Framed wall sections are then lifted into position on the base assembly. The loading imposed by the new retrofit work is transferred to the house structure directly through the supporting perimeter assembly. The framed wall is generally fastened to the rafter tails of the house, and provided with lateral support at the mid-section of multi-storey houses.

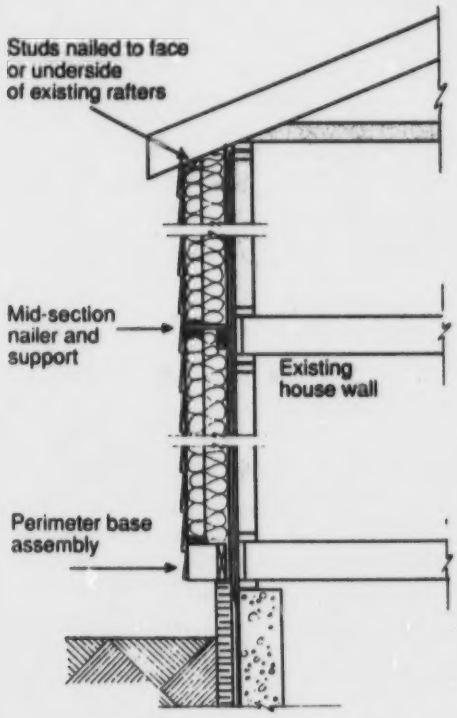


Fig. 7.8 Curtain wall supported by perimeter base assembly

Insulating the curtain wall should be performed in two stages to reduce convective air movement within the wall assembly. The first layer of insulation should be installed horizontally behind the studs. The second layer should friction fit vertically between the studs. Depending on the thickness of the new curtain wall, insulation values will range from RSI 3.5 to RSI 5.6 or higher.

Framing of the curtain wall can use either 38 x 64 mm or 38 x 89 mm lumber. Wall framing can employ standard platform framing techniques, although smaller dimension top and bottom plates 19 x 64 mm will be acceptable where no loading is being transferred to the plates. Framing for windows and doors can be done as part of the initial layout or they can be framed in place.

Perimeter Base Assembly

The loading of the retrofit wall is transferred to the house structure through the perimeter base assembly. The design and fastening of the assembly will vary, depending on several considerations:

- the **amount of insulation** required in the retrofit wall which will dictate the required width of the assembly;
- the **loading** imposed by the retrofit wall which may require the use of a stronger assembly option; and
- the **house section** to which the base assembly is being fastened.

Option A, as illustrated in Figure 7.9, is an easily installed base assembly which is compatible with a lightweight wall located no more than 140 mm from the main house wall. Note the minor thermal bridging across the ledger plates.

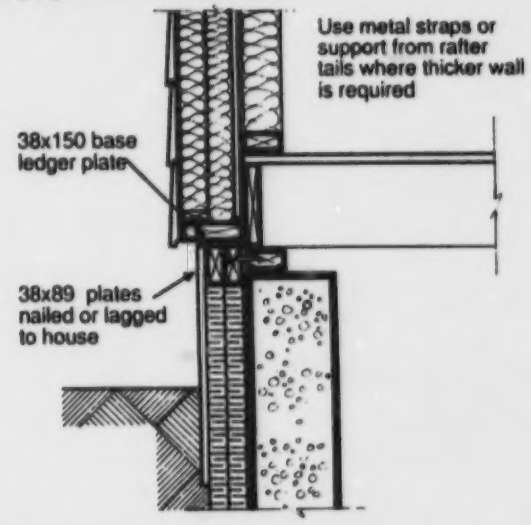


Fig. 7.9 Lightweight base assembly

Option B (Figure 7.10) is a more substantial base assembly which can accommodate wider and heavier wall strategies. The base assembly is prefabricated and then fastened to the house wall.

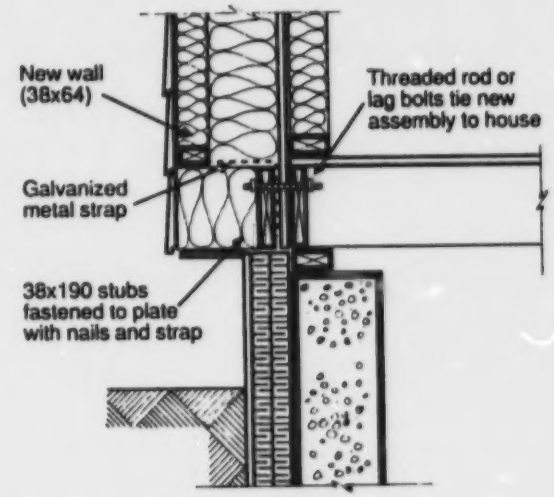


Fig. 7.10 Stub base assembly

Option C (Figure 7.11) involves diagonal bracing of the base assembly back to the house structure with a galvanized metal strapping, usually at every other stud space. To reduce complications, the assembly should be temporarily supported until the frame wall is in place. This will allow for easier installation of a prefabricated wall with the strapping subsequently being installed.

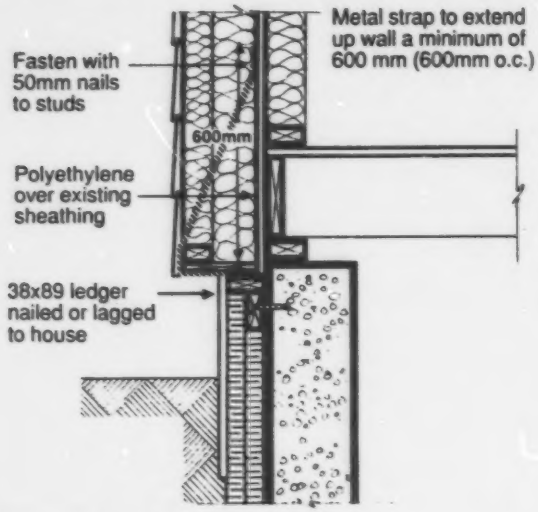

Metal strap to extend up wall a minimum of 600 mm (600mm o.c.)
Fasten with 50mm nails to studs
600mm
Polyethylene over existing sheathing
38x89 ledger nailed or lagged to house

Fig. 7.11 Braced assembly

Ceiling Junction

The framed wall system can be attached to the underside of the rafter tails or roof joists to prevent any lateral movement. The wall sections can be shimmed to fit the exact opening, or the rafters can be cut back. The contractor will determine the easiest technique for attachment of the wall section, whether it involves mitering the studs or using the existing soffit. Soffit ventilation must be maintained or relocated (Figures 7.12 and 7.13).

Maintain soffit ventilation using baffles
Studs nailed to rafter tails or framed to underside of rafters
New fascia and soffit
Sheathing paper and new cladding
New air barrier

Fig. 7.12 Rafter/wall junction

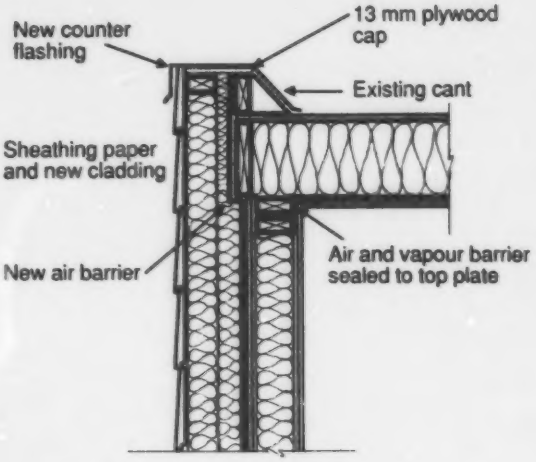

New counter flashing
13 mm plywood cap
Existing cant
Sheathing paper and new cladding
New air barrier
Air and vapour barrier sealed to top plate

Fig. 7.13 Flat roof/wall junction

Note that the polyethylene air barrier is sealed to the wall top plate which acts as the junction between the outside air barrier/vapour barrier and the inside existing barrier. An alternative approach would see extruded polystyrene installed around the house perimeter top plate between the ceiling joists (Figure 7.14). The polyethylene is then sealed to the rigid board.

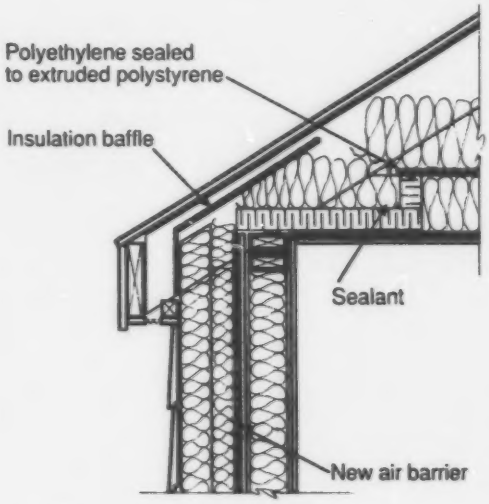


Fig. 7.14 Sealing with extruded polystyrene

Framing Options

When designing for multiple-storey buildings, a second supporting plate may be required at the mid-section of the wall. This plate does not need to be as strong as the base plate assembly but will be needed to tie the wall sections back to the house. Loading will be picked up by the main base plate assembly. Where stud lengths of longer than 3 m are being considered, bracing to the house wall may be required at mid-point in the retrofit wall (Figure 7.15).

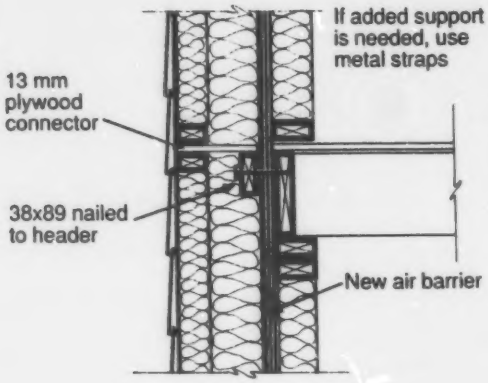


Fig. 7.15 Mid-section connection

Windows and Doors

Figure 7.16 demonstrates a technique for extending the sill and casing of a window which is not being relocated in the wall assembly. With a wide sill extension, prepainted metal flashing should be considered to reduce weathering damage. Figure 7.17 demonstrates the tying together of the interior wall to the retrofit wall using a 12 mm plywood liner. A new window would then be installed in the retrofit wall opening. The interior finish could involve drywall returns, wood casing and/or an extended sill of wood or tile.

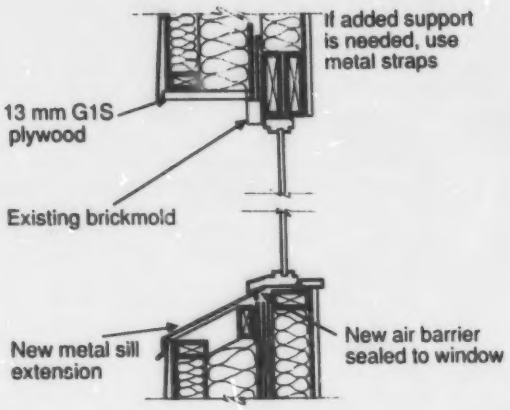

If added support is needed, use metal straps
13 mm G1S plywood
Existing brickmold
New metal sill extension
New air barrier sealed to window

Fig. 7.16 Window extension/metal flashing

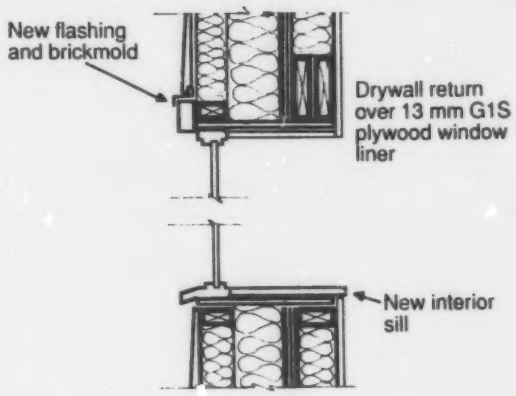


Fig. 7.17 Window extension/plywood liner

7.2.2 *Truss Wall Fastened to House Studs (Figure 7.18)*

This exterior retrofit strategy involves fastening wall truss sections over the existing house after the air barrier/vapour barrier is installed. The truss sections are fastened to the structure of the house at the top plate and rim joist, with optional support being provided by fastening to the house rafter tails and studs. Spacing of the truss sections will be at 600 mm o.c. or 400 mm o.c. to facilitate insulation and sheathing/siding installation. Fastening of the truss to the house will require a minimum nail length of 90 mm, allowing for a minimum 25 mm penetration into the house studs or plates. Nails or screws are fixed through the inner 38 x 38 mm chord. A plate made of 13 mm plywood will need to be fastened to the base of the truss wall to prevent air circulation and the entry of snow, insects and rodents.

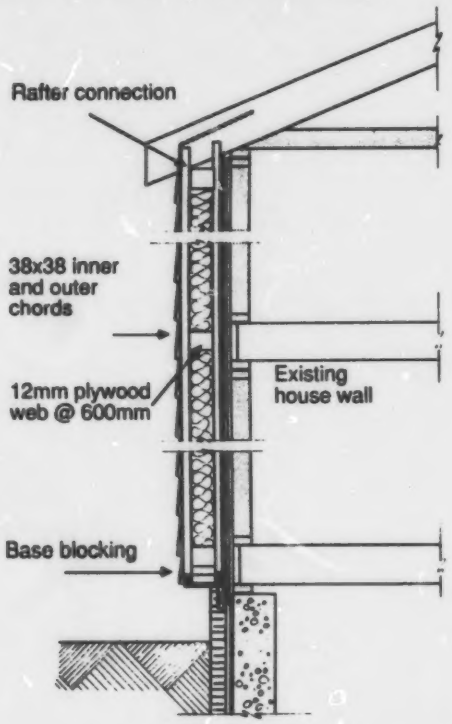


Fig. 7.18 Truss wall fastened to house studs

Friction-fit fibreglass batts are the conventional insulation option. Depending upon the configuration of the truss sections, an extra-wide batt may be required to prevent convective loops between the inner and outer chords. These batts are commonly available in RSI 4.9 thicknesses.

Major design considerations include

- means of fastening to house structure;
- depth of truss;
- truss configuration; and
- prevention of vertical air channels.

Truss wall installation can be more difficult on houses with uneven surfaces or dual surface elevations where fastening of the truss to the existing house structure is difficult. Unless the existing siding is removed, providing a firm backing for the truss, installation will require significant shimming. The truss must be aligned plumb or difficulties will arise when casing around windows and doors.

Truss Configuration

Several alternative truss designs have been employed in retrofit applications. The contractor may purchase the truss sections prefabricated, or may assemble the sections on the site. This will depend on the availability of materials, supplies and equipment, and labour. Price and ease of installation will determine the preferred alternative.

Option A — Larsen Truss (Figure 7.19)

This pre-assembled wall truss consists of 38 x 38 mm chords spanned by 8 mm to 12 mm plywood webs. The plywood is let into a dado cut in the two chords, and is designed to provide an overall thickness of 190 mm for the truss. The installation of sheathing or strapping over the insulated truss wall may be required for different siding techniques. The installation of the truss sections at 600 mm o.c. will facilitate the later installation of insulation and sheathing/siding.

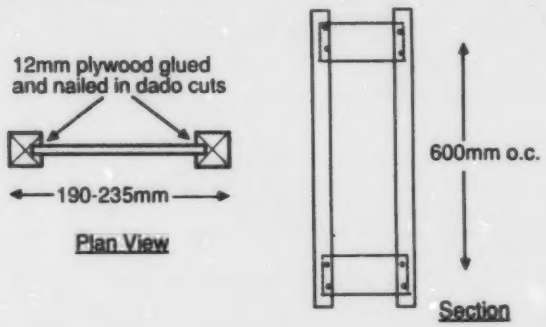


Fig. 7.19 Larsen truss

Option B — Face Nailed Web (Figure 7.20)

This truss consists of 38 x 38 mm chords spanned by 12 mm plywood webs. The plywood webs are face nailed to the chords at 600 mm o.c., and provide an overall thickness of the assembly ranging from 150 mm to 300 mm. A layer of rigid insulation is installed between the 38 x 38 mm chords to restrict air circulation between the inner and outer chord. The insulation should be 38 mm wide to provide a continuous surface between the chords. The material used between the chords could be polystyrene or urethane boards. A tight fit of the insulation is recommended. The installation of the truss section at 600 mm o.c. will facilitate the later installation of insulation and sheathing/siding, unless reduced centres are required for nailing the siding .

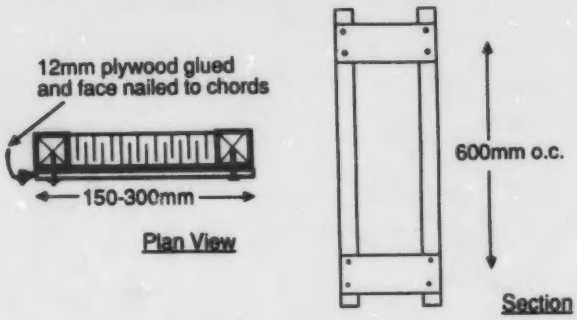


Fig. 7.20 Face nailed web

Note: it is recommended that the wood used for truss fabrication be kiln-dried. This should reduce handling problems associated with warpage and twisting.

Base Assembly (Figure 7.21)

The base of any truss wall section must be sealed to restrict cold air from blowing and circulating through the retrofit wall. The base section should also restrict the entry of any insects, rodents and snow. Installation of the wall trusses can accommodate several base plate options. Codes will require that any exposed wood within 200 mm of finished grade be pressure-treated.

Option A

This base assembly dictates that the truss sections be assembled with a longer outer chord than inner chord. A 38 x 89 mm ledger plate is lagged or nailed to the house foundation providing a non-structural base for the inner chord. The outer chord extends a further 50 mm lower and is then stiffened with the addition of a 38 x 38 mm base nailer. If the base of the assembly is less than 200 mm above grade, 12 mm sheet of preserved-wood plywood must be nailed across the span from the house to the outer chord. Nailing from the underside of the plywood can be eliminated by pre-assembly of the entire base plate.

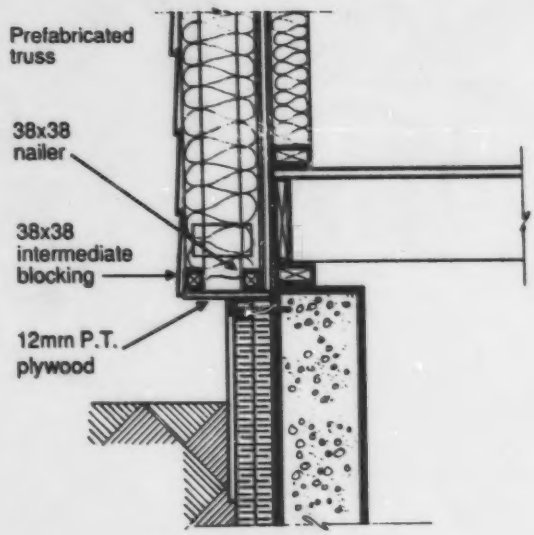


Fig. 7.21 Framed base assembly

Option B (Figure 7.22)

This plate assembly is a minor variation on the system detailed above. The system employs a pre-assembled base consisting of 38 x 38 mm member spanned by pressure treated plywood. The base blocking is nailed directly to the outer chord and is held in place against the house by a 38 x 63 mm nailer which is installed after the truss sections have been fastened in place.

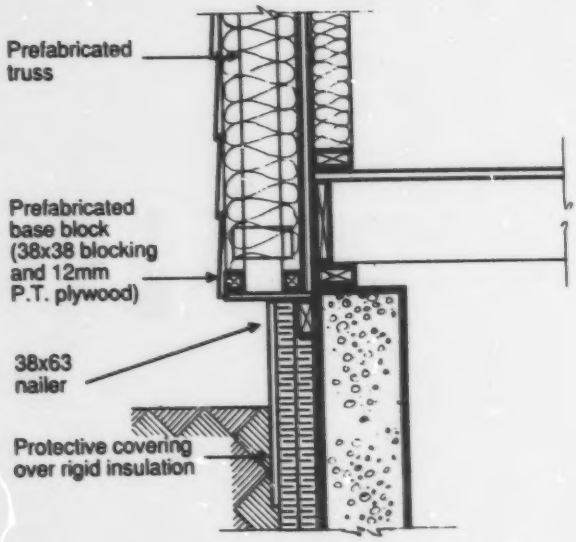


Fig. 7.22 Prefabricated base

Rafter/Top Plate Junction

Truss sections can be designed to accommodate a variety of details at the top of the new wall.

In an ideal situation, the existing house soffit is removed, allowing the air barrier to be sealed to the existing top plate of the house. Under this scenario, the truss sections are nailed to the rafter tails and gable lookouts to provide stiffening at the top of the truss wall. Where spacing of the truss sections does not coincide with the rafter spacing, 38 x 38 mm or 38 x 89 mm blocking can be nailed to the top of the outside chord and to the rafter above (Figure 7.23).

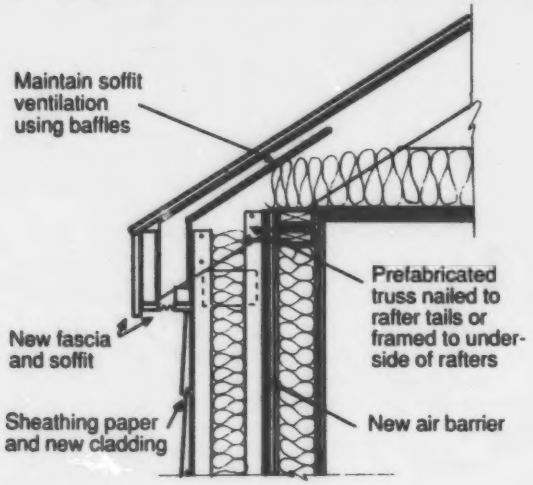

Maintain soffit ventilation using baffles
Prefabricated truss nailed to rafter tails or framed to underside of rafters
New fascia and soffit
Sheathing paper and new cladding
New air barrier

Fig. 7.23 Rafter Junction

Alternatively, where the existing soffit is not being removed, the truss sections can be cut to fit under the existing soffit. This may require that the soffit vents be extended to allow for continuous ventilation of the attic. To provide lateral rigidity to the top of the wall, blocking can be cut and nailed between the outer chords, or a 38 x 38 mm plate can be nailed to the underside of the soffits.

Windows and Doors

Rough openings for windows and doors are framed with 38 x 89 mm headers between the truss sections acting as the side framing. The rough opening should be framed to 25 mm greater than would normally be done to accommodate the 12 mm plywood liner which spans from the outer chord to the house (Figure 7.24).

Corner Detailing

For outside house corners, two prefabricated trusses can be fastened together in an L-shaped configuration. The right-angled truss is then fastened to the existing house at the corner of the building, allowing the other end of the L to extend to the

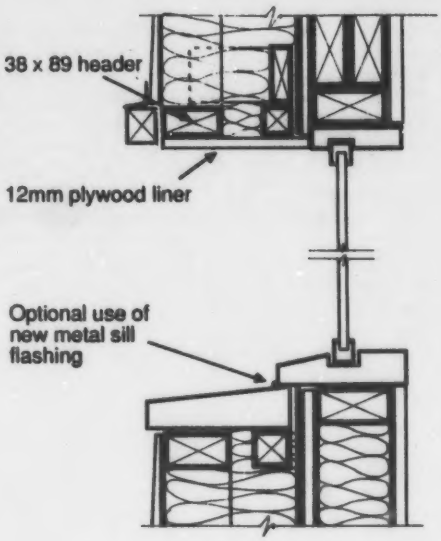


Fig. 7.24 Window detailing

plane of the other wall. To provide additional support, horizontal truss sections can be nailed at 600 mm centres between the corner truss and the first truss fastened to the house.

Inside corners can be easily framed using two individual truss sections (Figure 7.25).

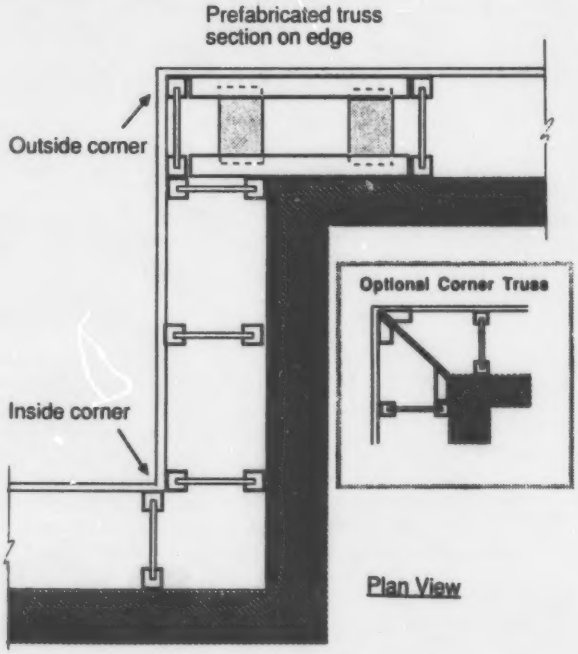


Fig. 7.25 Corner detailing

7.2.3 Strapped Wall (Figure 7.26)

This exterior retrofit technique involves installing a layer of horizontal strapping over the existing house walls after installing the air/vapour barrier and then fastening an exterior frame over the strapping. This approach to exterior retrofitting can accommodate insulation to levels of approximately RSI 3.5, depending on the 1/3 – 2/3 rule.

Strapping can be installed at 600 mm o.c. or wider if a rigid board insulation were to be fitted between the horizontal strapping. The horizontal strapping can be

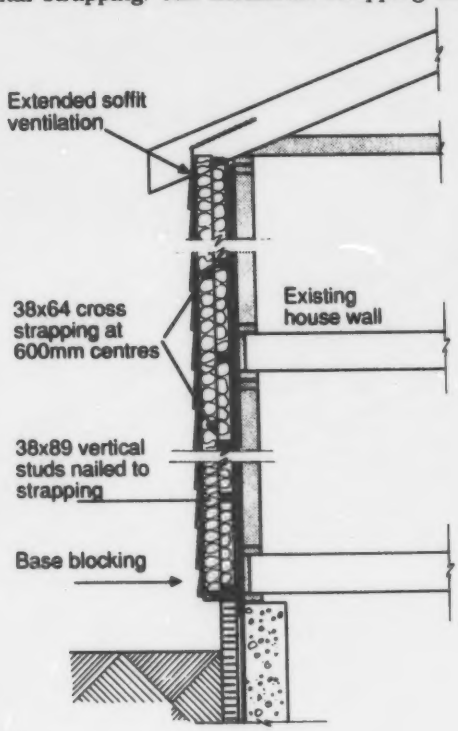

Extended soffit ventilation
38x64 cross strapping at 600mm centres
Existing house wall
38x89 vertical studs nailed to strapping
Base blocking

Fig. 7.26 Strapped wall

either 38 x 64 mm or 38 x 38 mm. Nailing on edge any lumber thicker than 89 mm is not advised. The strapping should be fastened to the house studs, wall plates or header joist. To maintain (or to upgrade to) plumb walls, shimming may be required. If using 38 x 64 mm strapping, an RSI 1.2 fibreglass batt can be fitted into the horizontal cavity. Strapping (38 x 38 mm) can provide a channel for 38 mm of rigid insulation, but this requires more attention to detail to provide a tight fit.

The vertical studs are installed at 600 mm centres and are through nailed with box nails or toenailed into each strapping layer. Alternatively, the 38 x 89 mm studs could be predrilled and then nailed with a 125 mm nail to the strapping.

The vertical studs can be either framed and lifted into place in manageable sections, or they can be individually installed. The former option will require additional top and bottom plates. The number of windows and doors in the elevation will be a factor in deciding which option to follow.

The major limitations to this approach to exterior retrofitting include

- allowance for a maximum RSI of 3.5; and
- lack of continuity of insulation.

7.2.3.1 Framing Options (Figure 7.27)

The configuration and dimensions of the wall framing will vary according to the original house siding, the amount of insulation required and the new siding to be installed. In a typical system, the initial layer of strapping will run perpendicular to the house framing. The strapping can be nailed through to the house studs, or if the lumber is 38 x 64 mm or 38 x 89 mm, it can be pre-drilled and then nailed to prevent splitting (Figures 7.27 and 7.28). If the finished siding is installed vertically, labour and materials can be saved by first strapping vertically.

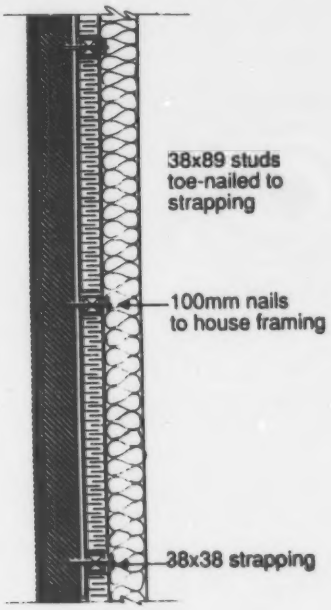


Fig. 7.27 38 x 38 strapping

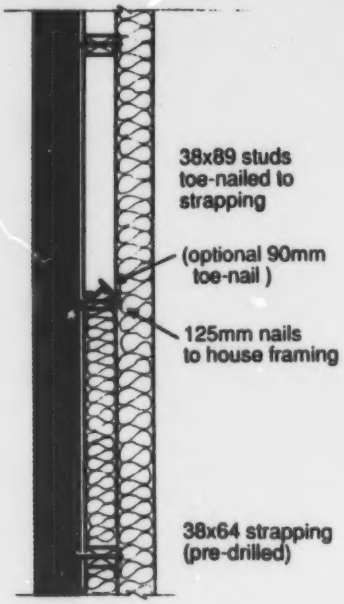


Fig. 7.28 38 x 64 strapping

The second layer of framing will generally be 38 x 89 mm toenailed or pre-drilled and nailed through to the horizontal strapping. This layer will be installed at 600 mm centres, allowing for standard sheathing and siding installation. The two strapping layers can be assembled into one unit on grade and lifted into place.

Base Detail

Detailing of a weathertight assembly at the base of a strapped retrofit wall can involve several different approaches. Any system must accommodate the following principles:

- any wood within 200 mm of the finished grade must be pressure-treated;
- a solid backing for the house siding must be provided; and
- air circulation into the strapped wall should be minimized.

The system detailed in Figure 7.29 demonstrates a base assembly employing a pressure-treated plywood plate nailed to the underside of the bottom row of strapping and wall studs. This option would involve installing blocking horizontally between the outside wall studs to provide added bracing of the assembly. Alternatively, a 38 x 140 mm bottom plate could be employed.

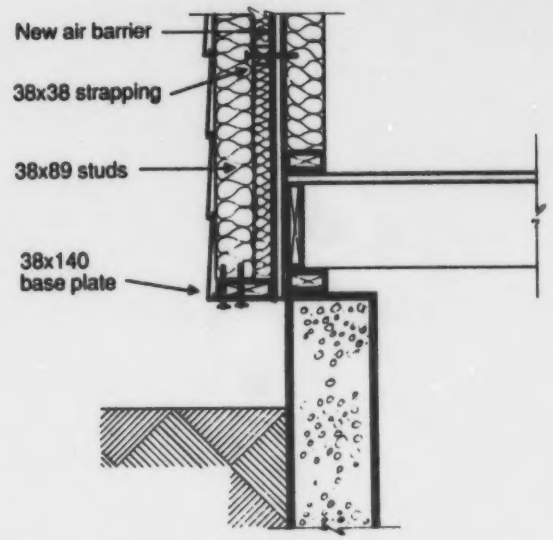


Fig. 7.29 Base detailing

Figure 7.30 illustrates a situation where the base assembly is used as a nailer for a protective coating over exterior below-grade insulation. The outside wall studs are toenailed to a 38 x 89 mm bottom strapping. By cutting the studs to the middle of the strapping, a nailing surface is left for the later addition of the exterior protective coating (metal lath and plaster, pressure-treated plywood, etc.).

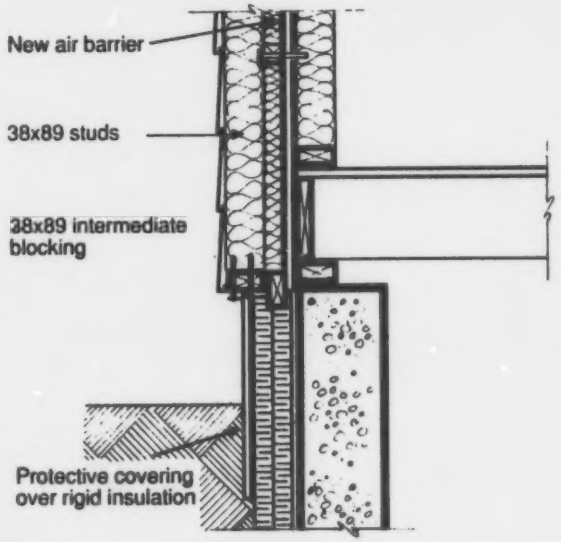


Fig. 7.30 Base detailing

Rafter Junction

The new wall studs can be installed to the underside of either the soffit or the rafter tails. The use of intermediate blocking between the studs at the top of the retrofit section will provide a nailing surface and will provide additional rigidity to the exterior frame (Figure 7.31).

Fig. 7.31 Rafter/wall junction

Windows and Doors

Window and door openings are blocked out to accommodate the increased thickness of the wall. The 38 x 38 mm blocking should span the width of the opening to allow the new wall stud to be fastened at the exterior rough opening. When extending the existing sill and casing, the seal between the old and new opening must be made weathertight. Alternatively, the second sill can be situated under the existing one (Figure 7.32).

When installing new windows, the entire opening can be lined in plywood, allowing the new window to be located at any position in the opening. New finishing of the returns and sill can accommodate a variety of materials.

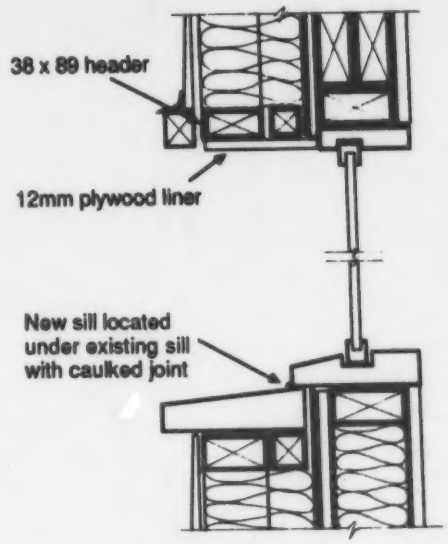


Fig. 7.32 Window detailing

7.2.4 *Curtain Wall Supported at Rafter Tails (Figure 7.33)*

This double-wall retrofit technique has been employed in many Canadian retrofit projects. The system consists of an exterior curtain wall frame of 38 x 64 mm or 38 x 89 mm studs supported from the rafter tails and at intermediate locations by nailers to the house structure. The system involves a considerable amount of prefabrication on site or in a shop, but results in reduced time for installation of the curtain wall.

The framing is installed on an individual stud-by-stud basis. Framing centres will be determined by the centres of the rafters as the curtain wall is hung from the rafter tails. This factor may lead to problems where poorly spaced rafters cause later difficulties with the installation of the insulation and siding. Ideally, the new curtain wall would be installed at 600 mm o.c. but it might be at 400 mm o.c. for certain siding applications.

The system can be designed to accommodate any amount of insulation, although the practical limit would be the addition of RSI 5.6. This insulation could be installed in a two-step process, the first layer (RSI 3.5) placed horizontally between the existing house and the back of the new wall, and the second batt being installed vertically between the studs. Care should be taken when fitting the batts around the nailing sections.

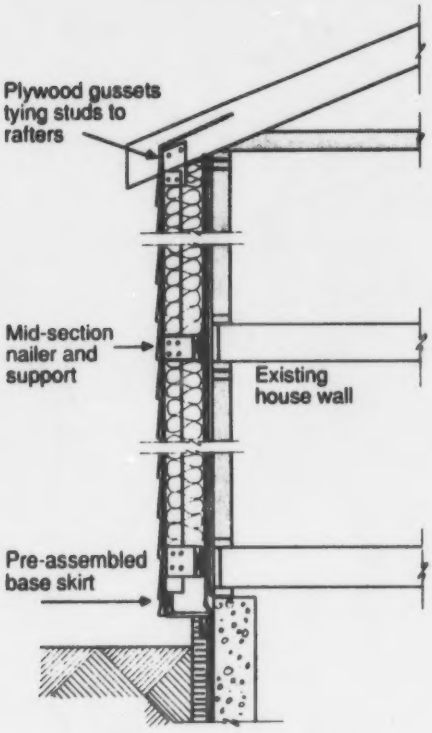


Fig. 7.33 Curtain wall supported at rafter tails

Rafter Junction

The new curtain wall is fastened directly to the existing rafter tails or truss chords with 12 mm plywood gussets on both or either side of the studs (Figure 7.34). The gussets are nailed first to the new studs, forming a sleeve to fit over the rafters. Where older, thicker-dimensioned lumber was used for rafters, the gussets may need to be shimmed out from the new studs. The gussets should be nailed to the studs with 38 mm galvanized nails. An alternative method involves nailing the rafters; this results in less work and fewer nails. Connection to the house rafter should ensure proper alignment — both plumb and equi-distant from the existing building. Accurate alignment with a chalk line will facilitate installation.

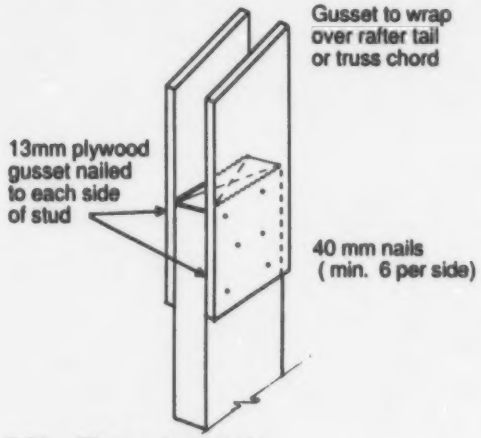


Fig. 7.34 Plywood gussets

Mid-Section Brace

The curtain wall is supported at the base and at the mid-section of multi-storey buildings with a separate nailing assembly. A 12 mm plywood plate spans the distance from the outside of the new stud to the existing house wall. The plate should be 300 mm high and should be nailed with 50 mm galvanized nails to the wall stud and to the edge of a 38 x 89 mm) nailer (Figure 7.35). The nailer assembly should be prefastened to the studs before installation. When the new stud wall has been properly plumbed and aligned, the 38 x 89 mm nailer is nailed into the house wall. Where some of the dead loading of the wall is being transferred by the nailing assemblies, the nailers should be bolted directly to a stud, plate or rim joist.

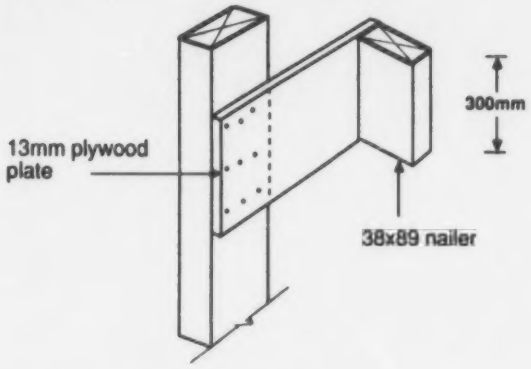


Fig. 7.35 Mid-section bracing

Base Assembly

The base of the new curtain wall must be sealed to prevent air circulation and to restrict the entry of snow, insects and rodents. The base section detailed in Figure 7.36 is a prefabricated L-shaped assembly which is hung from the base of the exterior 38 x 89 mm wall studs. The assembly consists of a 12 mm pressure-treated plywood face which is edge-nailed to a pressure-treated 38 x 89 mm blocking. The entire assembly is lifted into position, square on the studs, and nailed into place. The continuous skirt assembly will provide some additional rigidity to the base of the curtain wall. The base plywood can be nailed to a pressure-treated nailer against the house. Sealing of this location is important to prevent cold air entry. With older, uneven surfaces, a good seal may require considerable amounts of sealant.

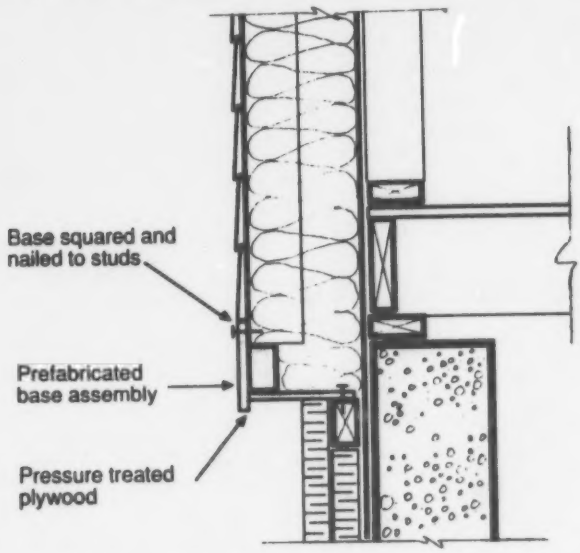


Fig. 7.36 Base assembly

Corner Detailing

Interior corner detailing can be easily detailed, although spacing of the house rafters may demand that the corner studs are braced directly to the wall rather than hung from the rafters. Where rafter spacing doesn't accommodate the corners, additional nailers can be installed onto the new stud, transferring the loading back to the wall plates or studs.

Exterior corners require a series of cantilevered blocking, extending out to support a corner stud. These can be framed with 38 x 89 mm blocking, which are nailed to the house corner stud and extend back to the first stud. The new corner stud is then nailed to the blocking, providing the required backing (Figure 7.37).

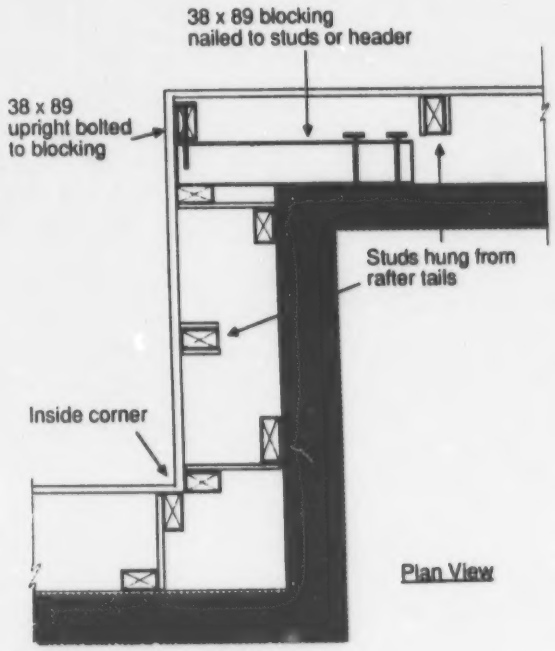

38 x 89 blocking nailed to studs or header
38 x 89 upright bolted to blocking
Studs hung from rafter tails
Inside corner
Plan View

Fig. 7.37 Corner detailing

Windows and Doors

Where the existing window is not being relocated or replaced, drainage from the existing sill to the new sill must be accommodated. Figure 7.38 demonstrates a technique where the new sill is framed to fit under the existing sill. The backing for the new window return is provided by 38 x 89 mm blocking, or by nailing a new casing over the existing window opening. Alternatively, a metal sill can be installed.

Where a new window is being installed as part of the retrofit, the existing opening and the new retrofit wall are joined by a plywood liner. This liner provides the option of installing the new window at any point within the wall opening. Proper waterproofing of the sill will be required if condensation is likely to occur.

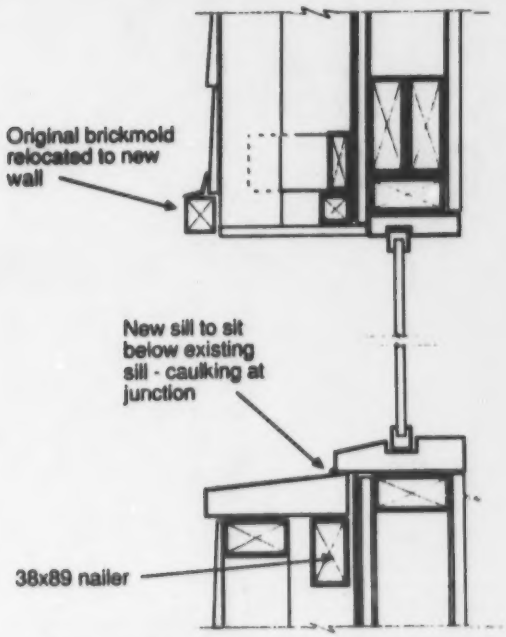


Fig. 7.38 Blocking around windows

7.2.5 Rigid Board Insulation (Figure 7.39)

An alternative exterior retrofit technique involves the application of rigid board insulation materials over the existing house walls. This approach has the benefit of allowing higher insulation levels per unit thickness and may prove to be the preferred option where spatial limitations prohibit the use of frame walls. Limitations of this system may include difficulties in hanging the new cladding, and possible deflections with certain combinations of cladding and insulation boards.

This section of the manual addresses the issues of installing rigid insulation materials to a level of RSI 3.5 or greater, usually in excess of 50 mm. Rigid board insulating sheathings are commonly installed in thicknesses of 25 mm or less under either new or replacement cladding. Where the contractor is considering a retrofit involving the application of rigid board insulations of less than 25 mm, reference should be made to *CGSB 51-GP-47 MP Manual for Installers of Insulated Cladding Systems.*

To be suitable for the application of most rigid board insulations, the wall surface must be smooth in order to allow for good contact between the wall and the insulation. This may involve the removal of old cladding before the new air barrier is installed over the sheathing. Alternatively, ripped batt insulation could be stapled to the existing siding before a layer of plywood or waferboard is installed as a nailer.

As with other systems described in this manual, rigid board materials may be installed using sheet polyethylene as the air barrier and vapour barrier. Alternatively, where the rigid board insulation has low permeance characteristics, the insulation itself

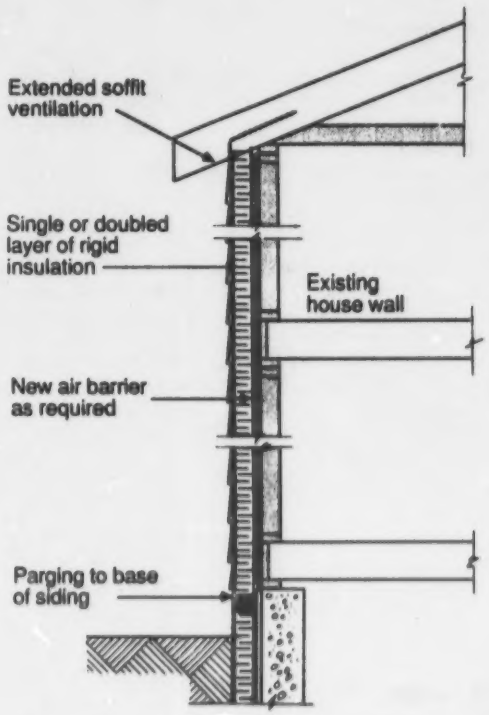

Extended soffit ventilation
Single or doubled layer of rigid insulation
Existing house wall
New air barrier as required
Parging to base of siding

Fig. 7.39 Rigid board insulation

may serve as the vapour barrier, allowing for the use of alternative air barrier installation. As always the 1/3 - 2/3 rule should be followed when determining the location of the air and vapour barriers.

Air barrier techniques for rigid board insulation will vary according to the material used. Some rigid board insulation materials constitute an acceptable air barrier if the seams in the material are sealed and taped. Techniques which are conventionally employed include the use of sealants and tapes over the seams. **Care must be taken that manufacturer's recommendations are followed. Many manufacturers of rigid board materials specifically recommend against the sealing of seams as impermeable materials could trap water.** The issue is further discussed in *CGSB, 51-GP-42MP, Handbook on Insulating Homes for Energy Conservation.*

Rigid board materials can be installed directly over the polyethylene, being nailed or fastened directly through the sheathing to the studs. Fasteners will be required along the length of the edge of the sheets (at 150 mm o.c.) and in a grid (300 x 600 mm) over the rest of the material.

The decision as to which fastening technique to use will be influenced by the proposed siding technique. Alternative fastening systems are illustrated in Chapter 5 of the manual. Installation of the finished cladding may require additional steps. The incorporation of an air space between the insulation and the cladding is recommended to prevent overheating of the siding. Some rigid board manufacturers will recommend specific fastening and cladding techniques.

Base Detail

As rigid board installation techniques will not require framing materials, the only requirements for the base plate relate to the inclusion of a ledger strip to allow for fastening of the bottom of the siding and appropriate flashing detailing. This ledger strip will be installed most easily prior to the installation of the board material. To limit problems further down the line the ledger should be installed level. The dimension of the ledger should accommodate the thickness of the rigid board materials and any air space, allowing for the easy installation of the cladding. Where an air space is included between the insulation and the cladding, the ledger should allow for drainage of any accumulated moisture (Figure 7.40).

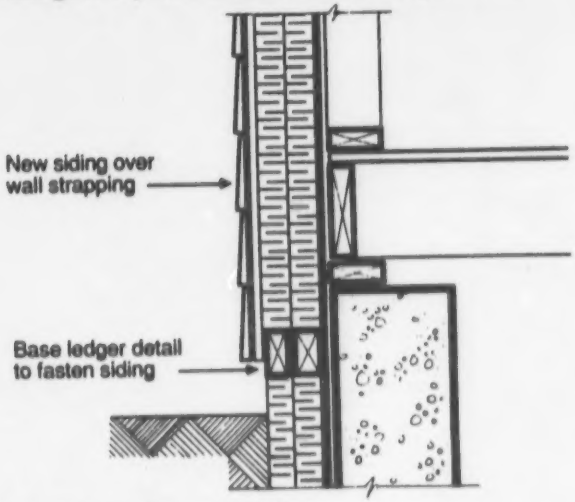


Fig. 7.40 Base assembly

Soffit Detail

The existing house soffit will have been removed as part of the wall preparation. The rigid board insulation should be extended up the wall to the top of the wall top plate. This will restrict thermal bridging across the wood but will require notching of the rigid board around the individual rafter tails (Figure 7.41). A nailing strip will need to be fastened through the rigid board to the wall studs as a nailer for the soffit.

Framing Around Penetrations

Additional nailers will be required around any penetrations in the house wall including windows and doors. While some cladding systems may not require additional nailing surfaces (e.g., where lath is installed), most cladding materials will require solid backing at penetrations. Nailers accommodating the thickness of the insulation materials and any air space should be installed flush to the outside of any openings (Figure 7.42). In some cases the contractor may decide to wrap the rigid board insulation around the return of the window. In this case, a second nailer butting against the jamb may be required.

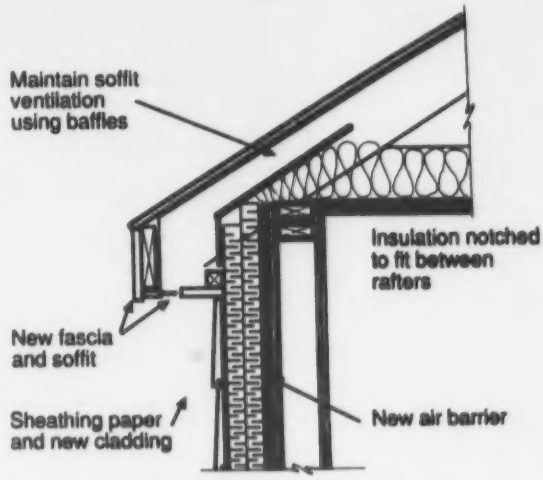


Fig. 7.41 Rafter junction

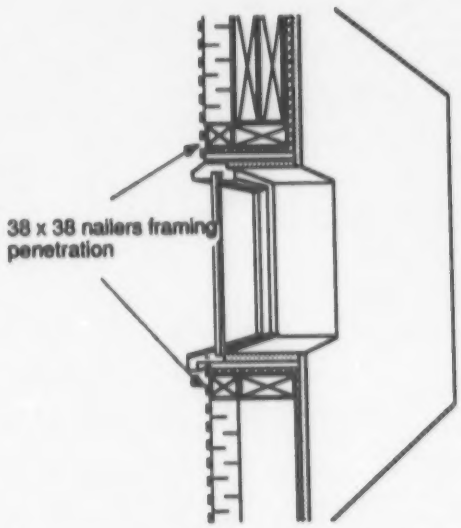


Fig. 7.42 Backing support at penetrations

Corner Detailing

To provide additional support at exterior corners, nailers must be required on both sides of the corner (Figure 7.43). For horizontal siding applications, the nailers will probably extend from the base of the wall to the bottom of the soffit, providing continuous backing. Stucco surfaces or vertically installed cladding materials may be installed without the extra nailers.

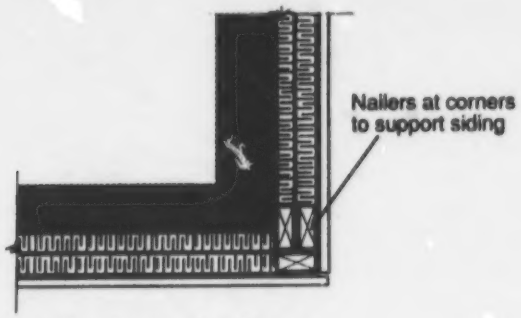


Fig. 7.43 Corner detailing

Sealing to Penetrations

Any penetrations through the rigid board insulation from the interior of the house will need to be sealed to prevent air and moisture movement. Where polyethylene is being employed as the main air barrier, the seal should be performed before the installation of the rigid board, using techniques as presented in Section 7.1.2.

Where a low permeance rigid board insulation is being used as the air barrier/vapour barrier, additional sealing will be required around the various penetrations in the house wall. The contractor should have the insulation installed to fit tightly around those penetrations which are not being relocated. The gap between the pipes, ducts, wires, etc., and the insulation material, should be caulked with an appropriate caulking material to provide a good seal (Figure 7.44).

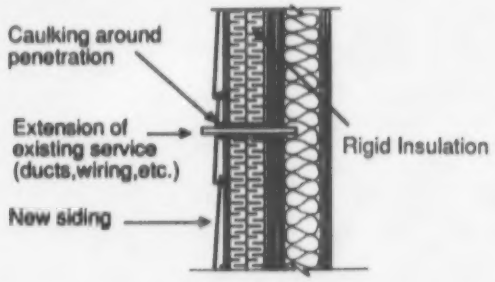


Fig. 7.44 Sealing at penetrations

7.3 SPECIAL STRUCTURES

Every old house is unique in its design, materials, general condition, and changes that have occurred throughout its lifetime. While this manual covers general techniques used in either interior or exterior retrofit, each house and circumstance has to be examined in its own right.

When confronted by unusual circumstances, the contractor has to rely on his understanding of the basic principles of retrofit. These include

- a continuous air barrier, sealed at all seams, edges and penetrations – any possible bypasses must be considered and blocked;
- an adequate vapour barrier located on the warm side of the insulation; and
- high levels of insulation installed to ensure a minimum of thermal bridging and elimination of cavities that could allow air circulation.

It is sometimes appropriate to insulate one wall from the exterior and another wall from the interior. This would happen where the street facade is to be kept unaltered. The corner where the inside retrofit and outside retrofit meet can be a difficult location to air seal and prevent thermal bridging.

One solution to this problem is to overlap the interior and exterior insulation as much as possible (Figure 7.45). This is especially important in masonry houses, where the masonry can act as a fin for heat movement. Of greater concern than heat loss is the movement of moisture into the junction, where it can cause damage. Air leakage should be stopped with interior air sealing, and vapour diffusion reduced by using a relatively impermeable paint.

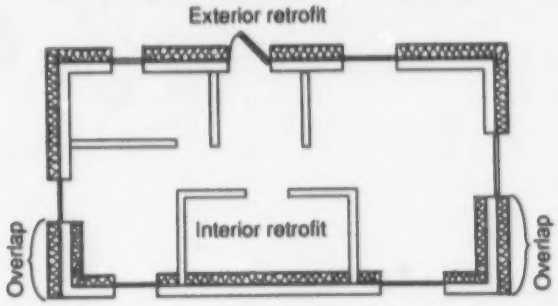


Fig. 7.45 Joining interior and exterior retrofits

Other common junction areas include

- at the sill with interior foundation insulation and exterior wall insulation (Figure 7.46);
- at the sill with exterior foundation insulation and interior wall insulation (Figure 7.47); and
- at the ceiling with exterior wall insulation and interior attic insulation.

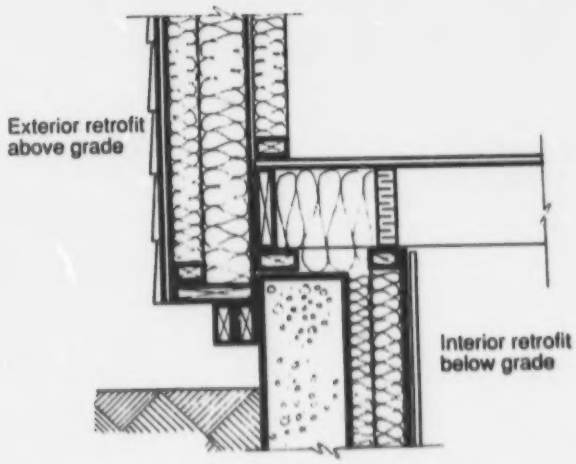


Fig. 7.46 Overlapping foundation insulation

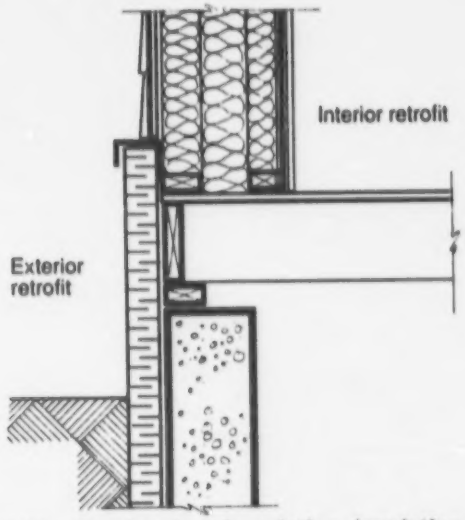


Fig. 7.47 Overlapping foundation insulation

7.3.1 Row Houses

Insulating a row house of masonry construction can prove difficult. The masonry exterior walls and separation walls can act as large fin radiators. If only one house in the row is insulated, then much of the effect will be negated by the heat loss along the walls to the neighbouring houses. This is especially true of exterior retrofit. If an exterior retrofit is being performed, insulation should be run along the separation walls for at least 600 mm. An air sealing job should be performed on the inside to prevent air leakage paths from the exterior, through the neighbour's wall and into the house (Figure 7.48).

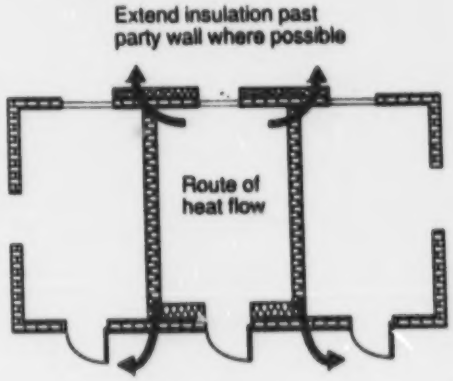


Fig. 7.48 Row housing

Houses which share a common wall often have a fire wall continuing up through the attic as far as, and sometimes past, the roof. If this is the case, the fire wall should be insulated where possible.

7.3.2 Semi Detached

Semi detached houses can create problems similar to those of row houses. Consideration should be given to overlapping insulation and air sealing from the inside to reduce air leakage paths. Another possibility is to approach the neighbours to see if they are interested in having a retrofit done at the same time.

7.3.3 Thermal Links

There are some circumstances, usually in inner-city neighbourhoods, where a thermal link may be appropriate. When two houses are separated by a narrow space (1 metre or less), it may be cheaper and more efficient to link the two houses thermally rather than insulate just one.

A full-wall thermal link consists of erecting insulated end walls at either end of a walkway between two houses (Figure 7.49). An insulated roof caps the link at the ceiling level.

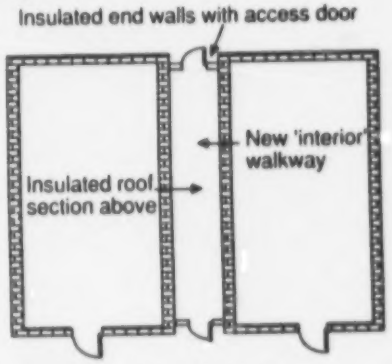


Fig. 7.49 'Linking' urban houses

Doors can be mounted at either end of the link to allow the space to be maintained as a walkway. This inner space is now heated space and the heat loss from the walls on both buildings is now effectively zero. As a bonus, the basement walls below the walkway are also thermally linked.

This type of construction obviously requires permission from all parties involved as well as a Committee of Adjustment ruling. Legal, zoning and fire implications must be considered.

A less ambitious, but effective technique, is to link only the basements thermally. The walkway between two houses can be capped with rigid insulation and the new concrete walk poured over the insulation (Figure 7.50), ensuring proper drainage away from the buildings. In this way, only the basements are thermally linked.

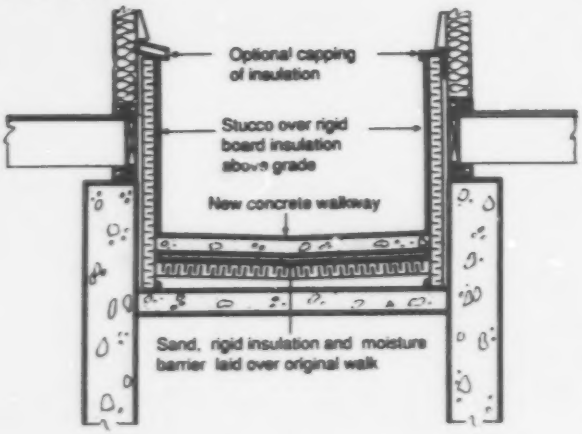

Optional capping of insulation
Stucco over rigid board insulation above grade
New concrete walkway
Sand, rigid insulation and moisture barrier laid over original walk

Fig. 7.50 Linking houses below grade

8

INTERIOR RETROFIT

Chapter 4 of this manual provides an overview of total retrofit work as performed from the inside of the house. While different interior retrofit techniques can result in significant energy savings and improvements in comfort, the work can be limited in its effect by the decrease in floor area, by the disruption to the household and by technical problems relating to continuity of the air barrier. Incorporating the retrofit into already planned renovation work will provide the greatest benefits.

8.1 DESIGN AND CONSTRUCTION GUIDELINES

This section examines the design and construction issues affecting interior retrofit. The specific approaches to providing high levels of insulation and improved airtightness are presented in Section 8.2 with detailed techniques and considerations. Each of the specific retrofit techniques has its own advantages and limitations, yet all interior retrofit strategies are similar in terms of the various stages which must be performed.

The major steps of an effective interior retrofit include

- Wall Preparation;
- Framing;
- Insulation;
- Air Barrier and Vapour Barrier Installation; and
- Finishing.

The following sections provide design and construction highlights for the different stages of the interior retrofit. Those principles and theories explained in Chapter 2 of this manual are highlighted in the text.

8.1.1 Wall Preparation

The contractor will need to assess whether the existing interior finish can be maintained. Generally speaking, the wall finishing is left in place when the cavity behind it already has some insulation, or where there is no substantial cavity (such as is the case with masonry buildings), and the plumbing and wiring services are in good condition. The wall finishing is generally removed if additional space for insulation is required or if the services inside the walls are to be upgraded. However, even if the existing cavity is uninsulated, it may be better to leave the wall in place. Insulation can be blown into the existing cavity instead.

If the existing wall is left in place, consider its possible role as an air barrier and vapour barrier on the cold side of the insulation when the newly insulated wall is framed in front of it. If the old wall has a polyethylene sheet vapour barrier (unlikely in older homes) or multiple layers of oil-based paint, some action must be taken to reduce the effectiveness of the wall as a vapour barrier. This could involve scoring the old wall with a saw or hammering holes in it along the top and bottom to allow any entrapped moisture to escape to the exterior.

Dealing with Existing Services House walls are interspersed with electrical wiring, plumbing, exhaust vents and other services (Figure 8.1). In most cases, the services will need to be relocated inside the new retrofit wall. In many cases, common sense as well as the *National Building Code of Canada (NBC)* will dictate your options:

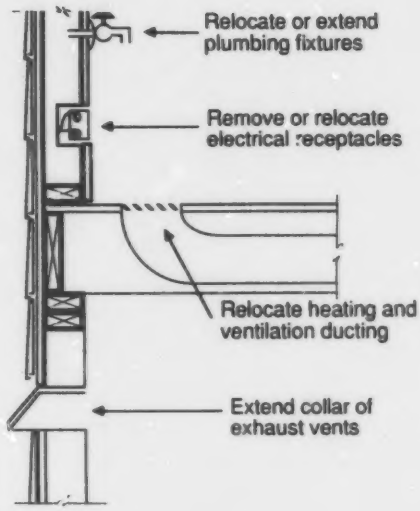

Relocate or extend plumbing fixtures
Remove or relocate electrical receptacles
Relocate heating and ventilation ducting
Extend collar of exhaust vents

Fig. 8.1 Implications for existing services

- plumbing lines and hydronic piping need to be relocated to the warm interior wall to eliminate the potential for freezing ;
- live electrical boxes cannot be left inside the existing wall;
- hot air ducting will need to be cut back to the inside of any new retrofit work; and
- through-the-wall exhaust vents may need to be extended to the inside with a new wall liner if a fan is located on the wall.

While most of the work will be easily done, extending the electrical outlets and switches to the inside of the retrofit wall may require some innovative approaches (Figure 8.2). It must be remembered that junction boxes cannot be buried inside of walls. Any electrical work must be done in conformance with local regulations. Any wiring work involving major changes to the system should be performed by a qualified electrician.

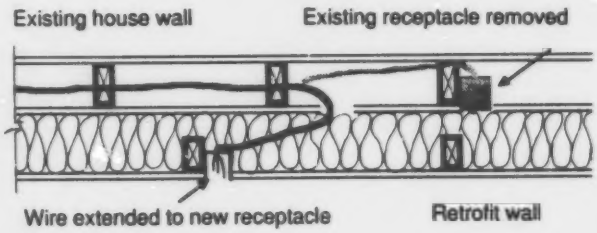


Fig. 8.2 Relocating existing receptacles to new interior walls

Advance Preparation for Installation of Continuous Air Barriers A considerable amount of preparatory work may be required to ensure that the job runs smoothly. Many built-in features of the house such as cupboards, stairs, or cabinetry should be removed before the retrofit work begins (Figure 8.3). An obvious trade-off exists between the improved thermal performance which can be obtained by removing and relocating these house features, and the considerable cost incurred in doing the work. Where it cannot be justified to remove built-in features, air sealing at seams and edges becomes very important.

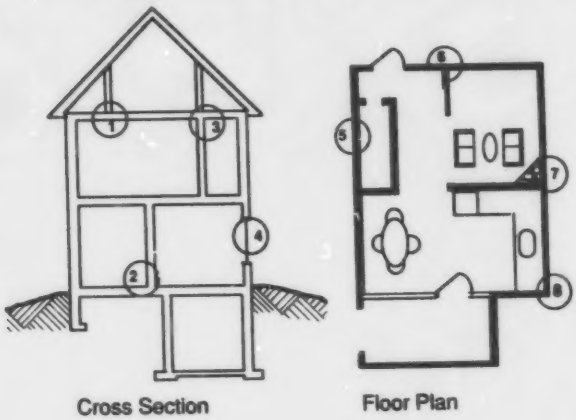


Fig. 8.3 Obstructions to air barrier continuity

A similar cost/benefit analysis will be required in considering continuity of the retrofit work between floors and through interior partitions (Figure 8.4). Where it is decided that the work can be justified, the following steps will be required:

Between Floors

- Joist cavities are most easily exposed by removing a section of the ceiling below.
- Try to limit the size of the exposed work to the depth of the proposed retrofit wall.
- If removing the sub-flooring from above, new blocking may be required for support.

Partition Walls

- If removing drywall or lathe and plaster, always cut it back to the centre of a stud to allow solid backing.
- Top and bottom plates of interior partitions must be cut back to the location of the finished retrofit work.
- Be careful when working around bearing walls and ensure that the walls are stable at all times.

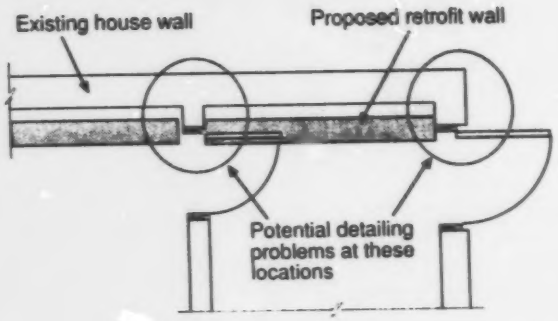


Fig. 8.4 Detailing problem areas

8.1.2 Framing

There are many techniques used to frame a new wall on the interior. Whatever technique is used, there are common characteristics (Figure 8.5).

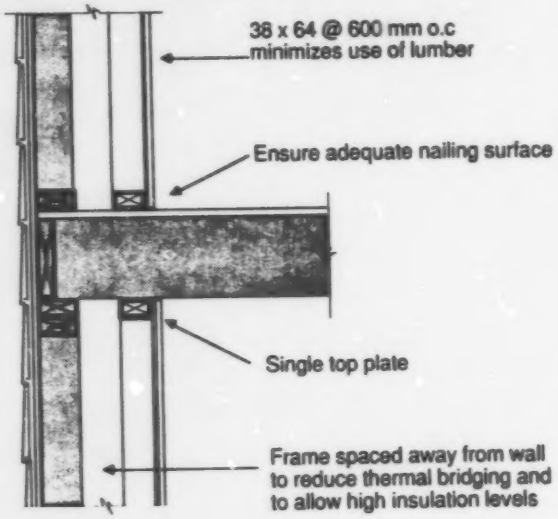

38 x 64 @ 600 mm o.c minimizes use of lumber
Ensure adequate nailing surface
Single top plate
Frame spaced away from wall to reduce thermal bridging and to allow high insulation levels

Fig. 8.5 Framing considerations

- Kiln-dried lumber should be used to reduce moisture build up in the wall cavity.
- The new wall has to provide a cavity to accommodate the required insulation levels.
- The wall should utilize a minimum amount of materials, for example, 38 x 64 mm framing 600 mm o.c.
- Thermal bridging should be minimized.
- The wall should be designed to accommodate standard insulation sizes.
- Provision should be made for sealing all penetrations including electrical outlets.
- The wall should provide adequate nailing surfaces for the drywall or other finishing material.
- The framing should provide adequate backing for baseboards, window trim, etc.

Three techniques for framing the wall are outlined in Section 8.2. These are

- **Curtain wall** consisting of a stud wall with top and bottom plates framed and pulled out from the old wall to the desired depth of insulation;
- **Cross-strapping** installed either horizontally or vertically to build up the desired depth; and
- **Rigid board** insulation is usually installed using a tracking system which provides a nailing base for the drywall.

8.1.3 Insulation

Most framing systems utilize glass fibre batts. These should be carefully installed following good construction practices. Where possible, this means installing the insulation in two layers; horizontally behind the studs, and vertically between the studs or cross strapping (Figure 8.6).

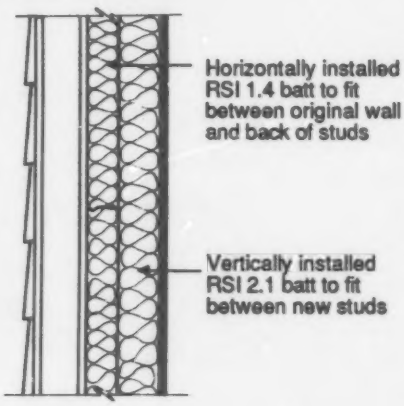


Fig. 8.6 Two-step insulation

Insulation should be placed in all available cavities, including the joist header space between floors. As discussed in Chapter 2, the compression of insulation will reduce it's effective RSI value.

8.1.4 Air Barrier Installation

The goal of whole house retrofit work is to create a continuous air barrier throughout the building envelope. A tight seal must be created where seams or edges occur and wherever there is a penetration through the air barrier. The most common technique for air barrier installation is the use of sheet polyethylene, usually of 0.15 mm thickness. An alternative technique uses drywall as the air barrier and paints or foil as the vapour barrier. Except where indicated, the following discussion is for the combined use of polyethylene as an air barrier and vapour barrier.

Seams between sheets and all edges must be mechanically fastened. The first sheet should overlap solid backing, such as a stud, by 150 mm. A continuous bead of caulking is run on the polyethylene, directly over the solid backing. The second sheet of polyethylene is pressed lightly over the caulking and staples driven through the bead into the backing every 150 mm. To complete the mechanical fastening, there should be a firm support nailed or screwed over the seam. This is often provided by the drywall. If there is not drywall installed directly over the seam, then a wood batten can be nailed over the caulked seam (Figure 8.7). The use of larger sheets of polyethylene will minimize the number of seams.

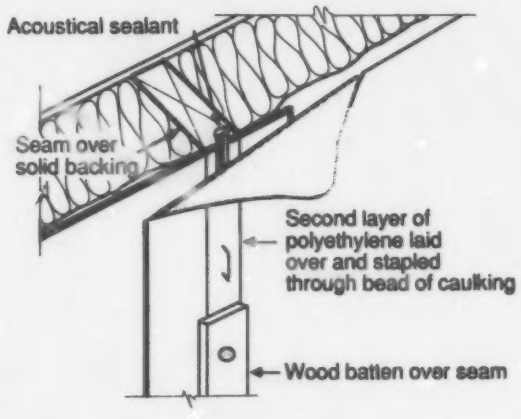


Fig. 8.7 Installing polyethylene

Acoustical sealant has been the preferred material for sealing polyethylene. The seal must be maintained over many years and therefore, the sealant must be pliable and non-hardening. Some contractors use contractor's tape, also mechanically secured by the drywall or batten.

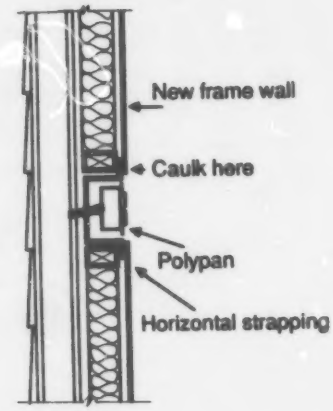
The use of staples on areas other than seams and edges should be minimized - there is no need to staple along each stud. Each staple hole is a potential air leakage path.

The polyethylene should be installed over window and door openings. Do not cut the polyethylene to the edge of the window or door trim. Leave extra polyethylene to allow for fastening to the door or window. Detailed window installation procedures are provided in Chapter 9.

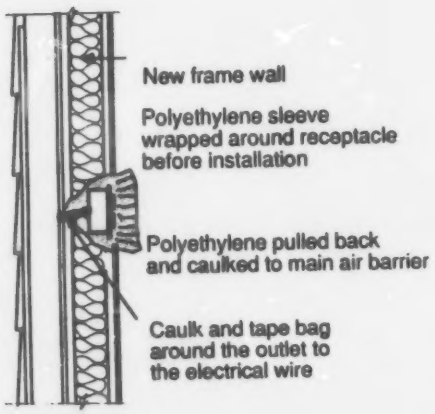
Carefully inspect the polyethylene before it is covered up. All holes, tears or weak seams should be marked and repaired with contractor's tape. Larger holes should be patched with a large piece of polyethylene. It is best to install the patch so that it overlaps onto solid support where it can be caulked and stapled.

All penetrations through the envelope should be sealed to the air barrier. Typical through-the-wall penetrations include any electrical boxes or lighting, plumbing services, vents, ductwork, and cable television and telephone lines.

There are a number of techniques for sealing electrical boxes where they penetrate the air barrier that is flush to the inside wall. Often a sleeve of polyethylene is taped to the wire, wrapped around the box and pulled back and caulked to the main air barrier. This has proven to be a difficult detail to seal. A better option is to place the box in a site-built or prefabricated airtight box. The only penetration through the box is for the wire. This hole should be caulked. The wall air barrier/vapour barrier is caulked to the front face of the airtight box (Figure 8.8). If a prefabricated box is used that does not provide a firm contact with the drywall, a plywood backing should be let-in between the studs to provide firm support.



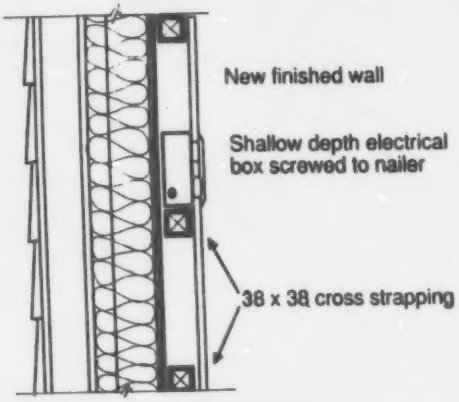
Polypan


New frame wall
Polyethylene sleeve wrapped around receptacle before installation
Polyethylene pulled back and caulked to main air barrier
Caulk and tape bag around the outlet to the electrical wire

Polyethylene

Fig. 8.8 Sealing electrical outlets

The preferred and easiest method of ensuring tightness involves cross strapping the wall studs over top of the air barrier. This technique allows the electrical boxes to be installed inside the air barrier in the strapping cavity. (Figure 8.9).



Cross strapped wall section

Fig. 8.9 Sealing electrical outlets

Plumbing lines should pass through a plywood backing board which is mounted flush with the inside face of the studs. The penetration holes should be cut to fit in the plywood and the seams caulked with a flexible sealant. Alternatively, a butyl rubber gasket can be mounted on the plywood with the plumbing lines entering through a small hole.

Ductwork and vents should be treated the same way as plumbing lines (Figure 8.10). A rigid plywood collar is cut to provide a tight entrance for the duct. The gap should be caulked with a flexible sealant. The air barrier is then sealed to the plywood using caulk and staples.

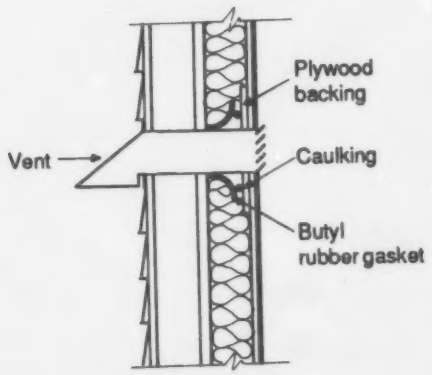


Fig. 8.10 Sealing vent penetration

Drywall can be used as the air barrier instead of polyethylene (Figure 8.11). Taping provides the seal at the joints. Penetrations are dealt with in a similar manner as described above. Difficult areas to seal are at the top and bottom plates and at floor junctions.

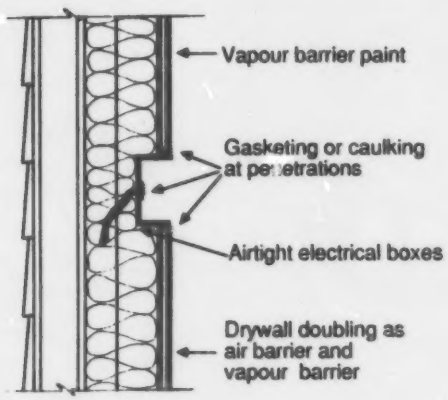

Vapour barrier paint
Gasketing or caulking at penetrations
Airtight electrical boxes
Drywall doubling as air barrier and vapour barrier

Fig. 8.11 Airtight drywall

Sealing of the drywall air barrier around electrical boxes is performed using airtight outlet boxes and by caulking the joint between the box and the drywall. Generally, gasketing material is stapled at these locations to provide a long-lasting, pliable, seal.

To provide a Type 2 vapour barrier as required by Code, various combinations of paints can be used, such as two coats of oil based paint. Alternatively, foil-backed drywall or polyethylene sheet with regular drywall will provide a vapour barrier.

8.1.5 Finishing

Finishing the wall will follow conventional practices, with the exception of the extra care required to prevent damage to the air barrier/vapour barrier.

Snap a chalk line at the locations of the studs or cross-strapping to ensure that drywall screws go into the wood.

Drywall should be precut, including outlet holes before installing (Figure 8.12). Cutting after installation will result in torn polyethylene.

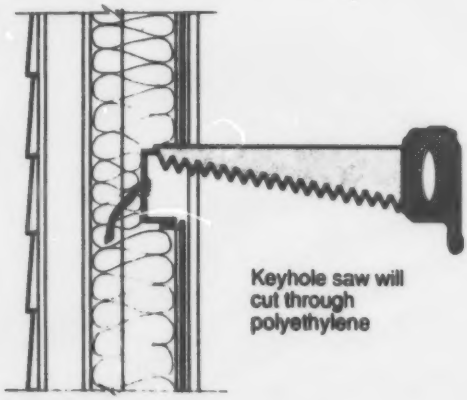


Fig. 8.12 Maintaining the air barrier

8.2 INTERIOR INSULATION OPTIONS

Chapters 3, 4, and 5 have identified the various evaluation and decision-making criteria which will guide the contractor and homeowner through the retrofit process. The following worksheets provide detailed instructions and guidance on the actual construction of interior retrofit work. The worksheets are presented in a manner which outlines an entire system, highlighting a preferred approach to the design and construction of the wall retrofit. Variations to the system are introduced where required.

It is assumed that each contractor will consider and develop alternative approaches reflecting regional materials and labour preferences. Design flexibility and contractor initiative are encouraged, providing that the basic concerns and considerations relating to good envelope design are followed.

The details incorporated throughout this manual assume that the contractor follows good building practices. No specific details relating to interior finishing or exterior siding installation have been included. Similarly, basic construction techniques such as nailing patterns, framing techniques, etc., have not been detailed. For those readers who are not professionally involved in construction, *Canadian Wood-Frame House Construction*, listed in Appendix B, provides a good fundamental background to construction techniques.

The following options for framing and insulating from the interior are detailed:

8.2.1 New Interior Frame Wall
8.2.2 Strapped Interior Wall
8.2.3 Rigid Board Insulation

8.2.1 New Interior Frame Wall (Figure 8.13)

This interior retrofit strategy involves the framing of a new 38 x 64 mm or 38 x 89 mm frame wall inside the existing house wall. The new wall can be pre-assembled at the floor, complete with top and bottom plates and all rough window and door openings.

The wall can be laid out and assembled at 600 mm centres. The height of the wall should be approximately 6 to 10 mm shorter than the existing floor to ceiling span to allow the wall to be lifted into place. Once located, shims can be wedged between the top plate and the ceiling joists.

The location of the new retrofit wall will be determined by the amount of insulation required. If adding RSI 3.5, the inside face of the wall will be located 140 mm from the finished wall surface. The addition of RSI 4.8 would see the inside face of the new wall located 190 mm from the existing wall. The new frame wall is nailed into the subfloor and joists below, and into the ceiling joists above.

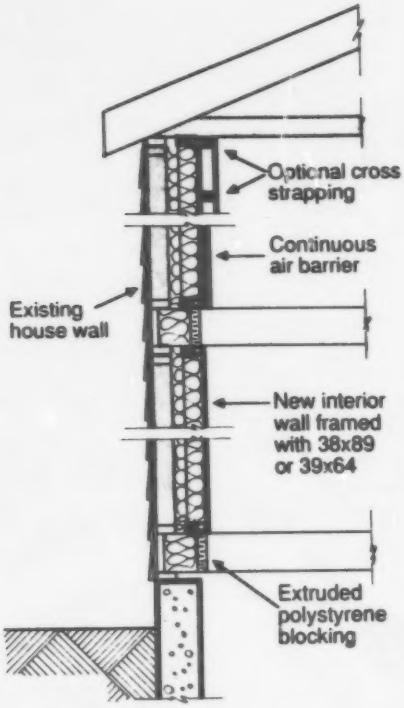

Optional cross strapping
Continuous air barrier
Existing house wall
New interior wall framed with 38x89 or 39x64
Extruded polystyrene blocking

Fig. 8.13 Interior frame wall

Installation of the insulation is performed in two steps, with a horizontal layer of insulation being placed between the original wall and the back of the newly framed wall, and a second layer of insulation being placed vertically between the studs. Combinations of batt thicknesses could include RSI 2.1 and RSI 1.4 or RSI 3.5 and RSI 1.4, assuming that 38 x 64 mm studs are used.

Openings in the walls (windows, doors, etc.) are lined with plywood or drywall.

Where new services — electrical and plumbing — are being installed as part of a major renovation, the addition of a layer of interior strapping can eliminate the need for penetrations in the polyethylene. A 38 x 38 mm interior strapping provides a chase for the wiring and plumbing between the polyethylene and the finished interior surface. The strapping is nailed over the frame wall at 600 mm centres. The cavity created by the strapping can be insulated with horizontal strips of batt insulation.

Between Floors and Partitions

The new frame wall will be located several centimetres inside the existing house wall. Maintaining continuity of the air barrier and insulation through partition walls and between floors represents the greatest challenge of the interior retrofit.

Partitions

Continuity from room to room can be attained by cutting back the framing and drywall to allow the new wall insulation and air barrier to pass through. By cutting the bottom and top plates, the new polyethylene and drywall can be installed continuously through the partition wall (Figure 8.14). Patching the partition wall is made easier if the original wall board or lathe and plaster is cut back to the centre of the first stud from the wall. A new piece of wallboard can be installed at a later point onto new blocking or onto drywall clips installed on the exterior wall.

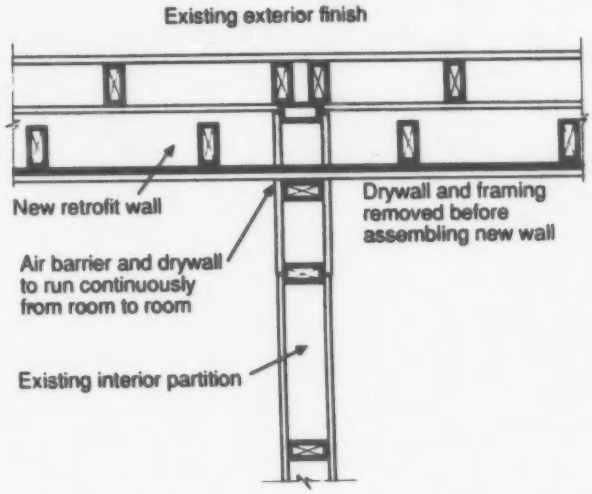

Existing exterior finish
New retrofit wall
Drywall and framing removed before assembling new wall
Air barrier and drywall to run continuously from room to room
Existing interior partition

Fig. 8.14 Continuing the air barrier between rooms

Floor Joist Assemblies

Providing a continuous layer of insulation and, more importantly, a continuous air barrier through the house floor joist assemblies will demand a considerable amount of work. The job is easier during a total gut renovation; however, in the majority of situations, the contractor may find it better to simply insulate and seal the joist cavities from below, leaving the house subfloor and finished floor intact.

This will normally involve cutting the ceiling back. Where the joists run parallel to the outside walls, the ceiling should be cut back to the centre of the first joist. Where the joists run perpendicular to the wall, the floor joists can be exposed only to the location of the new frame wall. This will minimize any later patching work (Figure 8.15).

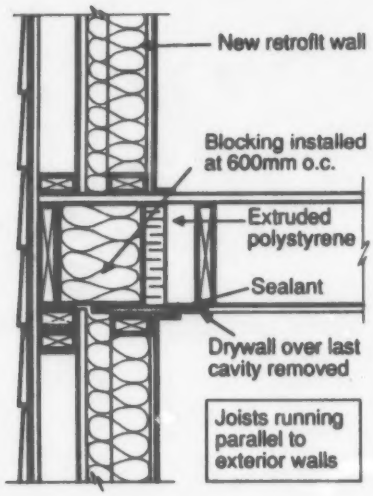


Fig. 8.15 Air barrier continuity between floors

Once the ceiling has been cut back, the cavity can be insulated and sealed using either a rigid board insulation, glass fibre batts encased in polyethylene bags, or spray urethane. Rigid insulation should be closely fitted to the joist cavity and should be caulked to the joists and to the subflooring using an acoustical sealant. Because of the limited space available, the insulation may need to be set back directly against the joist header (or rim joist) to allow the caulking to be installed (Figure 8.16).

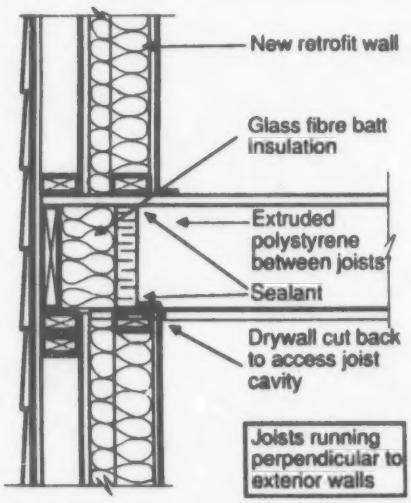

New retrofit wall
Glass fibre batt insulation
Extruded polystyrene between joists
Sealant
Drywall cut back to access joist cavity
Joists running perpendicular to exterior walls

Fig. 8.16 Air barrier continuity between floors

To provide an effective air seal, the polyethylene should be sealed directly to the rigid insulation in the joist cavity. Where the insulation is pushed back against the joist header (or rim joist), a sleeve of polyethylene may be needed to provide a junction from the joist/cavity insulation to the main air barrier on the wall. The polyethylene strip should be caulked to the under side of the joists and to the insulation and then should be mechanically fastened with a scrap of wood or batten. The polyethylene strip can then be temporarily stapled to the ceiling before the new retrofit wall is installed. Continuity of the air seal is provided by sealing the polyethylene.

Floor Joist Assemblies - Gut

Where the house is being totally gutted, providing continuity of the insulation and air barrier is much more easily accomplished. While the joist cavity is exposed, the insulation and air barrier can be easily installed, caulked and sealed. Where the joists run parallel to the exterior walls, a connecting strip of polyethylene can be installed to join the air barrier above and below. Where the joists are perpendicular to the exterior wall, a combination of rigid board insulation and the polyethylene as described above will prove the best option (Figure 8.17).

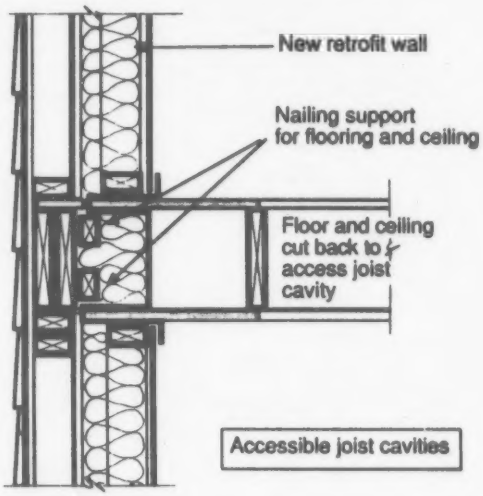

New retrofit wall
Nailing support for flooring and ceiling
Floor and ceiling cut back to access joist cavity
Accessible joist cavities

Fig. 8.17 Air barrier continuity between floors

8.2.2 Strapped Wall

This technique for interior retrofit involves the installation of a layer of strapping over the existing wall of the house, or the technique can be employed as an additional step to the strategy outlined above. When installed over the existing walls of the house, cross strapping can allow for some additional insulation while permitting improved airtightness. In conjunction with interior framed wall strategies, cross strapping is primarily used as a means of allowing easier installation of a continuous air barrier.

Cross strapping over existing house walls will increase the thickness of the wall, allowing for upgraded insulation levels (Figure 8.18). This strategy, in isolation, will not often be merited, but as part of a reinsulation of the existing cavity, the additional step can be justified. When a new wall surface is to be installed, upgrading of the existing cavity can be easily performed. This is particularly true for frame-wall consruction. (Most masonry construction does not provide a space for insulation greater than on 18.5 mm strapping.)

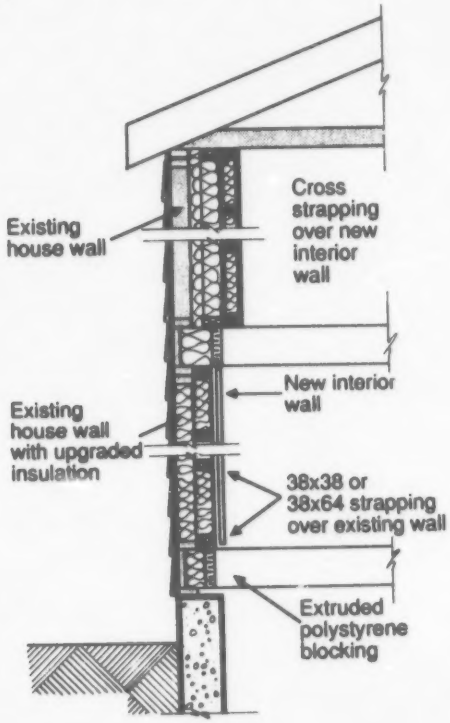

Existing house wall
Cross strapping over new interior wall
New interior wall
Existing house wall with upgraded insulation
38x38 or 38x64 strapping over existing wall
Extruded polystyrene blocking

Fig. 8.18 Interior frame wall

Most conventional upgrading of existing cavity insulation will involve one of the following techniques:

Blown-in-place glass fibre, mineral wool or cellulose insulation can be installed without causing a major disruption of the house interior (Figure 8.19). These insulation materials can be installed directly into the existing wall cavities using conventional blown-in-place techniques. All applications should be performed according to procedures established by the Canadian General Standards Board as presented in *51-GP-44 MP Manual for Installers of Cellulose Fibre Blown Loose Fill Thermal Insulation* and *51-GP-45 MP Manual for Installers of Mineral Fibre Blown Loose Fill Thermal Insulation.*

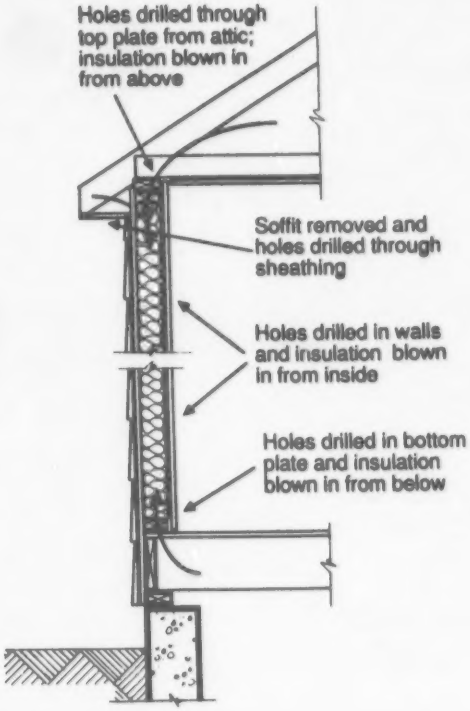

Holes drilled through top plate from attic; insulation blown in from above
Soffit removed and holes drilled through sheathing
Holes drilled in walls and insulation blown in from inside
Holes drilled in bottom plate and insulation blown in from below

Fig. 8.19 Blowing options

Reinsulation with batt insulation, either glass fibre or mineral wool, will require the removal of the existing interior wall surface. While this is not generally a concern with houses undergoing a major transformation, the resulting mess may be a liability in inhabited homes. Exposing the existing cavity is most easily justified where the insulation levels are poor – either because of older construction techniques, or on account of deteriorating insulation (wall moisture, UFFI insulation, etc.). Proper installation techniques, as described in Chapter 2, will result in tight-fitting insulation in the cavities.

After the existing insulation has been upgraded through one of the above-mentioned techniques, a new air barrier and vapour barrier can be installed over the existing wall in the form of sheet polyethylene. The following steps can be employed in the incorporation of new interior frame wall systems as outlined in Section 8.2.1. By installing the air barrier and vapour barrier before the strapping, the barrier remains recessed in the wall and is less susceptible to damage throughout the construction process (Figure 8.20). Continuity of the air barrier through floors and walls will follow details as described in the proceeding section.

The material used in the cross strapping of the wall can be either 38 x 38 mm or 38 x 64 mm in dimension (Figure 8.21). Strapping of 38 x 64 mm can be nailed on edge to provide a slightly larger cavity for the installation of insulation, although its installation is more difficult. The 1/3 - 2/3 rule of placement of the air and vapour barrier must be followed. The benefit of

the enlarged cavity will need to be traded-off against a loss of interior floor area. With both dimensions of lumber, the contractor will want to check for warpage of the wood and changes in the thickness of the lumber, either of which might lead to later problems in wall finishing.

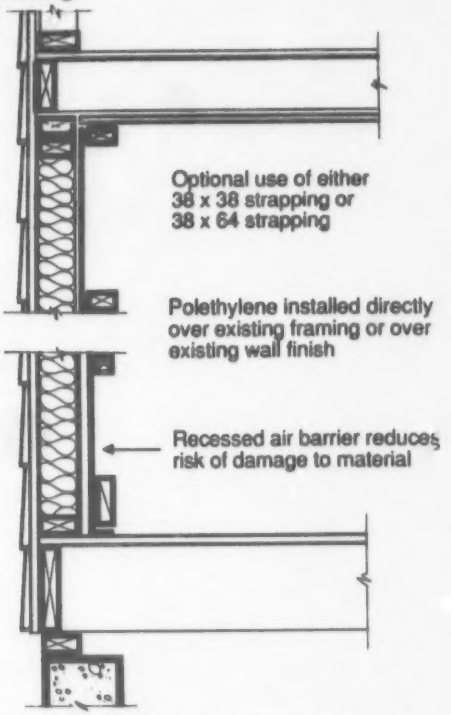

Optional use of either
38 x 38 strapping or
38 x 64 strapping
Polethylene installed directly
over existing framing or over
existing wall finish
Recessed air barrier reduces
risk of damage to material

Fig. 8.20 Cross strapping over new air barrier

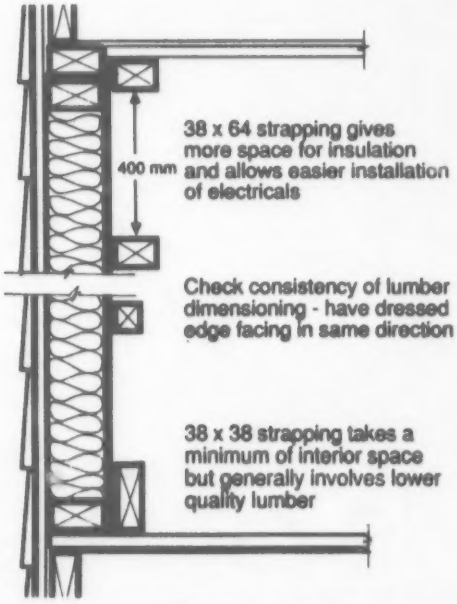


Fig. 8.21 Cross strapping: sizing and spacing

Spacing of the strapping could be on either 400 or 600 mm centres. The wider spacing may result in the potential for greater wall deflection and might legitimize the use of a thicker wallboard. Spacing of the cross strapping at 400 mm on centre will result in greater labour and material cost.

The cross strapping must be installed to accommodate electrical and plumbing lines and fixtures as well as finishing details for walls and trim. Support will be required for the following elements of the wall assembly.

Baseboards A larger piece of wood will be needed at the base of the wall to provide backing for the baseboard. This is most easily provided by installing a 38 x 89 mm strapping layer at the base, or by installing a second layer of 38 x 38 mm at the height of the top of the baseboard (Figure 8.22).

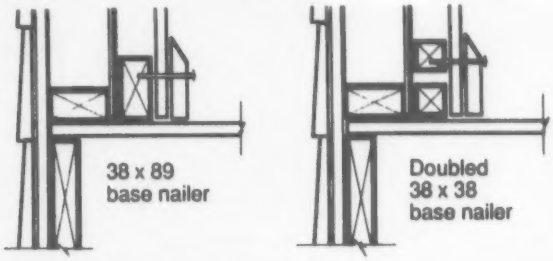


Fig. 8.22 Nailers for baseboard

Windows Additional strapping or blocking will be needed to trim out windows for the wall board. The blocking should provide support for the window returns or jamb extensions as well as for the required trim and casing (Figure 8.23).

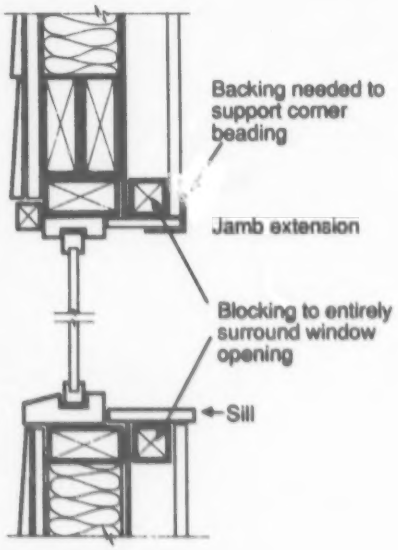


Fig. 8.23 Blocking around windows

Corners Blocking may be required to provide adequate support at corners throughout the house. The vertical blocking can be installed over the existing studs at the corner. One alternative to this technique involves the use of drywall clips to minimize the amount of blocking needed (Figure 8.24).

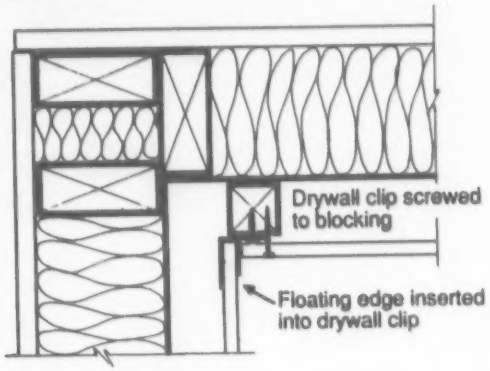


Fig. 8.24 Corner detailing

Plumbing and Electrical Boxes Plumbing lines projecting into the living area will require some supporting blocking. This may involve vertical blocking directly over the frame of the wall behind. Vertical blocking will be needed to support electrical boxes for outlets, switches and receptacles. The blocking will run over the studs in the main frame of the wall.

Once the strapping and/or blocking has been totally installed, the contractor will have the option to insulate the cavities or simply to install the finished wall over the empty cavity. While the additional insulation will have some benefit in reducing heat loss, the contractor will need to evaluate the benefits in relation to the costs of supplying and installing the material.

Installing insulation into a 38 mm cavity can pose several problems. Batt insulation of 38 mm is not currently available on the market. If the contractor wants to use a batt insulation, a thicker batt (RSI 1.4) will need to be ripped. This is not only time consuming, but unpleasant. Batt insulation for a cavity created by 38 x 64 mm strapping is readily available. A final alternative would involve the use of a rigid board insulation betweeen the cross strapping. This approach is often complicated by the blocking, wiring and plumbing which interrupts the cavities. The use of a foil-backed drywall against an empty cavity can provide enhanced energy performance, although it is suspected that, over time, the thermal performance of the foil-backed material will deteriorate as the foil picks up dust.

Finishing details for a cross-strapped wall will follow standard construction details. It should be remembered that the wallboard being installed should still be installed perpendicular to the framing members. This will involve the vertical application of drywall, with the associated inconvenience of vertical seams. Any penetrations required in the wallboard should be precut so as not to cut or tear the newly-installed polyethylene.

8.2.3 Rigid Board Insulation

This interior retrofit strategy involves the application of rigid board insulation to the inside of the house walls. This approach can allow for insulation levels approaching RSI 3.5. Beyond this level, fastening of the interior wallboard becomes difficult. The use of rigid board insulation on the house interior has the advantage of allowing higher insulation levels in a reduced space and alleviates the need for any framing.

As with the option of cross strapping, where work is planned on the interior of the existing house walls, the contractor will have the opportunity of upgrading the insulation levels of the existing house walls. This will be most applicable when dealing with wood frame construction.

The different materials which can be employed as an interior rigid board insulation have been described in detail in Chapter 5. The main options include expanded or extruded polystyrene, polyurethane, or polyisocyanurate, although other materials can be employed. The decision as to which material to use will be primarily influenced by the required insulation level and the cost of the various options.

Several fastening systems are available for applying rigid board insulation over existing walls as illustrated in Figure 8.25. The contractor should be sure that the fastening system used allows for a mechanical fastening of the finished wall board to the house frame. Where the thickness of the rigid board insulation restricts the fastening of the wallboard to the frame, one of the systems which provides an intermediate nailer should be considered.

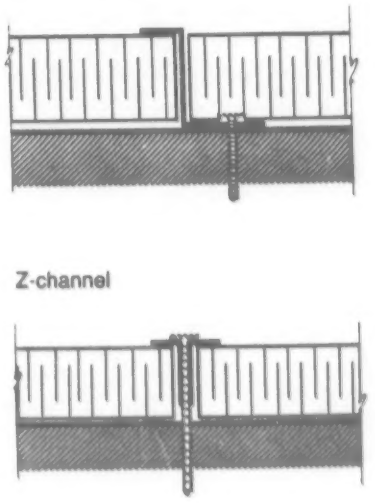
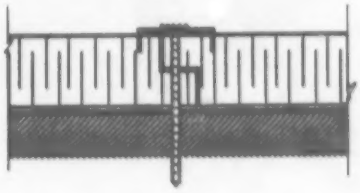
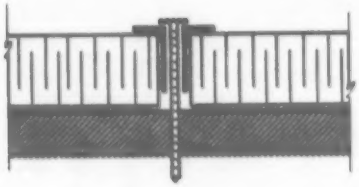


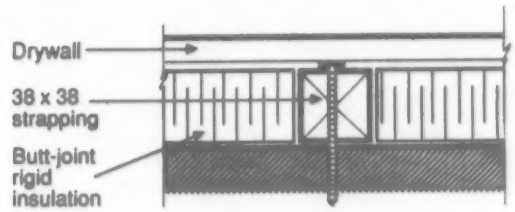
Fig. 8.25 Mechanical fastening systems



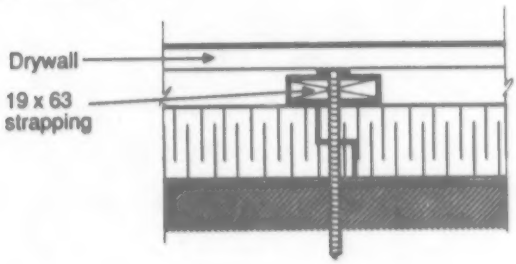
Insulok M.S.C.



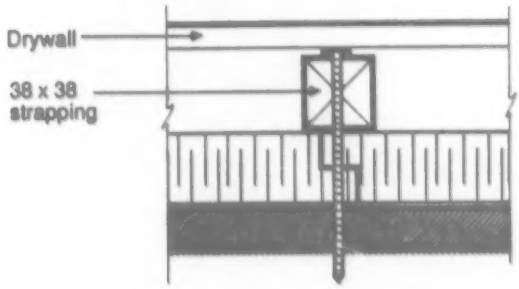
L-channels



Wood strapping



Surface mounted strapping



Surface mounted strapping

Fig. 8.25 Mechanical Fastening Systems cont.

Where a double thickness of the rigid board insulation is being employed, the first board can be installed with reduced structural concern as long as the outer layer allows the required mechanical fastening of the finishing material to the frame. Where this is the case, the initial board could be held in place with a mastic.

Where rigid board material is being installed in conjunction with cross-strapping systems, the contractor will need to account for standard centres for the strapping. This will require ripping of the insulation board to fit between the strapping layers. Cutting of the boards should be carefully done to reduce air circulation between the strapping and the insulation. As an alternative, the contractor might consider using a rigid board material with a shiplapped edge, allowing for the strapping and insulation to be installed at the required centres.

The use of rigid board insulation materials is most significantly restricted where the existing wall is irregular or where the upgraded wall has a large number of services. While non-rigid materials can conform reasonably well to irregularities and services, most rigid materials will require additional work. Irregularities in the existing wall can result in air pockets behind the insulating board. These pockets can affect the performance of the insulation by allowing convective air movements. The impact of these convective air movements can be decreased by applying a mastic to the existing wall in a grid before application of the insulation (Figure 8.26).

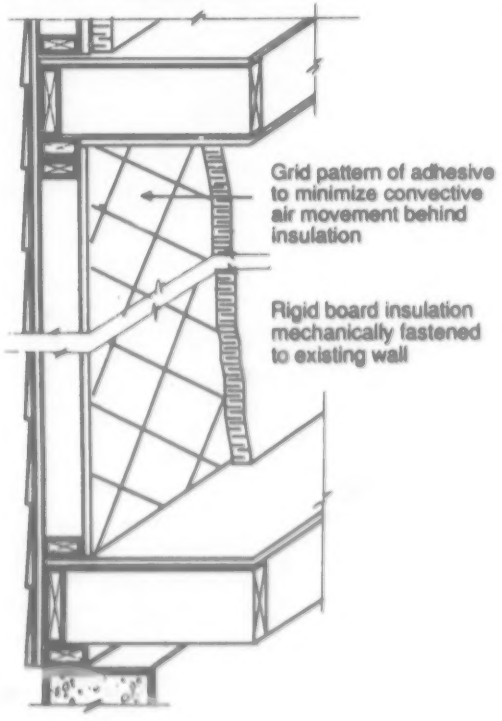


Fig. 8.26 Restricting convective air movement

Electrical and plumbing lines will require additional work in making the rigid board conform to the services. Relocated or extended electrical outlets will require additional blocking for support of the boxes. The back of the rigid board may need to be notched to accept the extended services running along the wall (Figure 8.27).

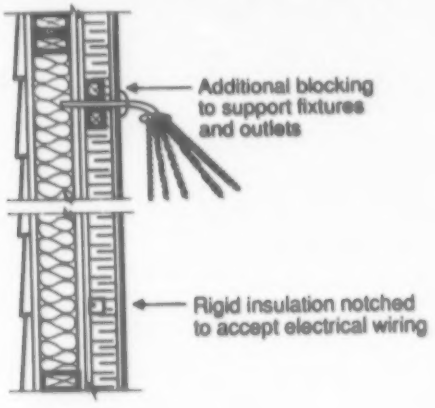


Fig. 8.27 Electrics and plumbing

Providing an air barrier and vapour barrier in conjunction with rigid board insulation can be accomplished in several ways. Sheet polyethylene can be installed directly over the newly-installed insulation prior to the installation of the finished wallboard. In this manner the polyethylene will serve the dual role of air barrier and vapour barrier. Continuity of the barrier between floors and walls can be provided in the same manners as discussed in 8.21.

Where the rigid board insulation material has a low permeance (i.e., restricts the flow of water vapour) only an air barrier is required. This can be provided if any seams in the rigid boards are carefully sealed. Sealing of materials can be performed by using either caulking materials or different tapes. The use of caulking as a sealant requires that the boards be installed in a tight fashion to reduce the gap and to minimize movement. Tapes are somewhat more elastic and can span slighty larger gaps.

In both cases the contractor should be certain that the sealing technique employed is compatible with the rigid board material. Where clarification is required, contact the manufacturer's technical representative. Sealing will be required at all vertical seams as well as at the junction of the insulation with the floor and the ceiling.

9

WINDOWS

Major retrofit work, whether performed on the inside or the outside of the house, provides an opportunity to evaluate the existing windows and upgrade or replace them. It is appropriate to consider the different options for upgrading performance as part of a whole house retrofit.

This section will review common window problems and opportunities presented by major retrofit work. Criteria to be used in evaluating house windows will be presented and the options available for upgrading and replacement will be described. A similar, although less detailed, discussion on doors is included.

9.1 PROBLEMS AND OPPORTUNITIES

Existing house windows can be the source of several problems. Poorly fitting windows can be a major source of discomfort by allowing the leakage of cold air. At the same time, a great deal of heated air will leak to the outside. Secondly, older single-glazed and many double-glazed windows offer a surface on which condensation and frosting can form. Not only are frosted windows unsightly but the resultant build-up of water on the frame and sill can cause structural damage. Further problems can arise from poorly designed window placement. The following issues can be the result of bad planning:

- inadequate natural lighting;
- excessive solar gains; and
- not taking best advantage of views.

The total retrofit will provide an opportunity to address existing window problems. It should be remembered that the retrofitted house may operate differently and that it may affect window performance. The increased insulation and tightening of the house may have the following effects:

- increased humidity levels may occur with the potential for more significant condensation/ frosting of windows; and
- reduced heat losses may increase problems of excessive solar heating.

The benefits which can be easily integrated into a broad retrofit program include the following:

- reducing air leakage around the window frame by proper sealing of the air barrier;
- relocation of windows to accommodate improved views, daylighting, solar gains and interior design considerations; and
- installation of new, higher thermal performance windows, which will save energy and reduce frosting and condensation problems.

9.2 WINDOW DESIGN CONSIDERATIONS

A complete evaluation of the house windows will include five major considerations:

- Structural Performance;
- Thermal Performance;
- Solar Performance;
- Architectural Performance; and
- Operational and Security Performance.

9.2.1 Structural Performance

Windows are subject to damage from the effects of:

- weathering;
- water run-off and driving rain;
- edge stresses on the glass or sealed unit;
- temperature extremes across the glazing;
- condensation on interior surfaces.

In assessing the material and structural condition of the house windows, it is important to diagnose the reason for material failure so that the replacement unit will have a longer service life.

There is an advantage to a whole house assessment of windows. With the exception of south-facing windows, it may be expected that all the units will experience equal deterioration. By comparing the relative condition of all windows, it will be easier to discover and diagnose severe problems caused by conditions particular to one window – such as missing flashing.

South-facing windows are an exception as they are exposed to greater extremes of temperature and solar radiation. In general, south-facing windows will deteriorate more rapidly. So also might those windows which are continually subject to higher humidity levels such as those in kitchens and bathrooms.

9.2.2 Thermal Performance

Windows are the weakest link in the house thermal envelope. Even a good window has an insulating value of only 10% when compared to a reasonably insulated wall section. The thermal performance of windows can be improved by addressing the major heat loss mechanisms.

Air Leakage

The main air leakage paths through house windows are illustrated in Figure 9.1.

- Between the sash and frame;
- Between the glazing and sash; and
- Between the frame and the rough opening.

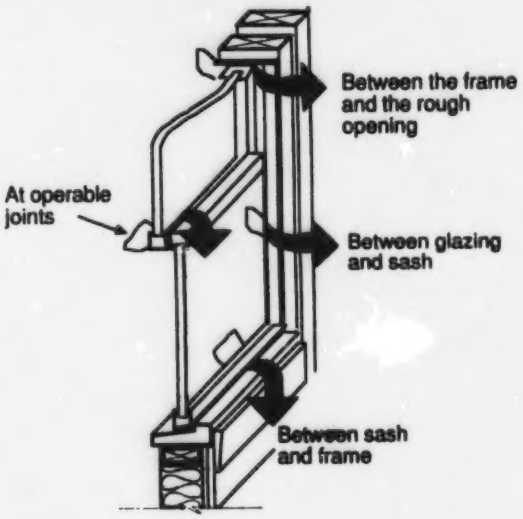


Fig 9.1 Window leakage

Proper installation of the new retrofit work can reduce leakage from around the outside of the window. Caulking and weatherstripping are needed to improve the other joints in the window (Figure 9.2). *Air Sealing Homes for Energy Conservation* (see Appendix B) provides detailed guidance.

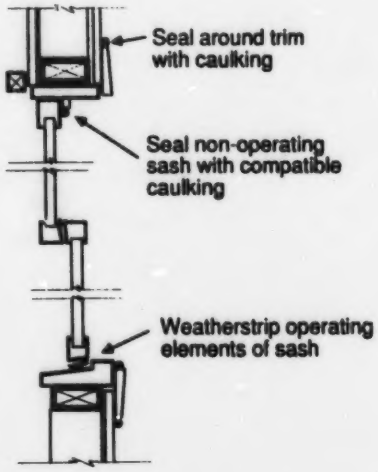

Seal around trim with caulking
Seal non-operating sash with compatible caulking
Weatherstrip operating elements of sash

Fig. 9.2 Caulking and weatherstripping

Conduction

- Glass is a poor insulator and heat is readily transferred by conduction across the pane. Transfer across the air space is by conduction, convection and radiation.
  - — Conduction can be reduced by gases.
  - — Convection can be reduced by creating multiple air spaces (Figure 9.3) or introducing inert gases.
  - — Radiant heat transfer can be reduced by the use of low emissivity coatings.

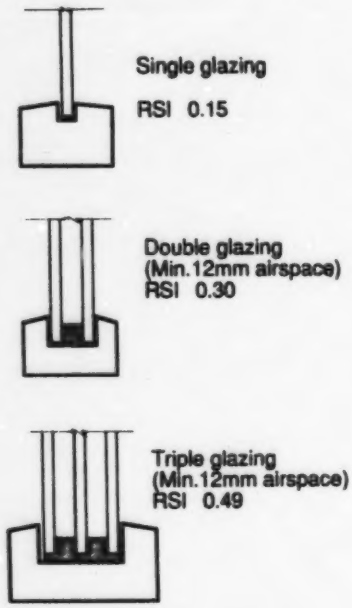


Fig. 9.3 Reducing heat loss through glazings

- The second major location for conduction in windows is the sash and frame. Metal conducts heat far more readily than wood or plastic. Metal windows should include a thermal break material in the frame to reduce conduction (Figure 9.4). Frosting on the interior face of metal frame windows is one indication of a missing or inadequate thermal break.

- Conductive losses may also occur across the edge of sealed units depending on the material used for the spacer.

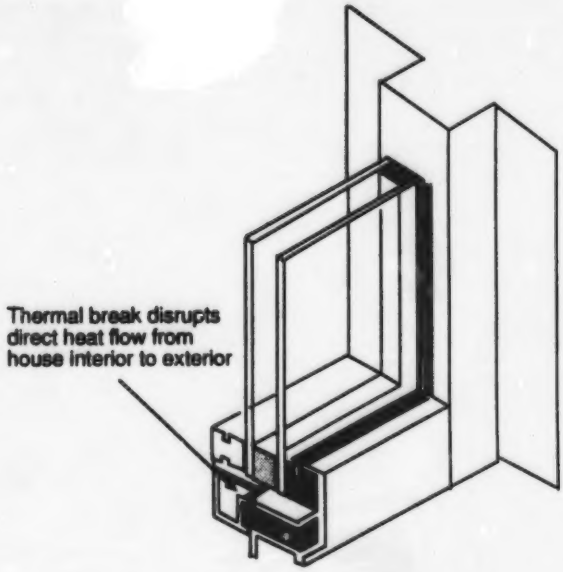
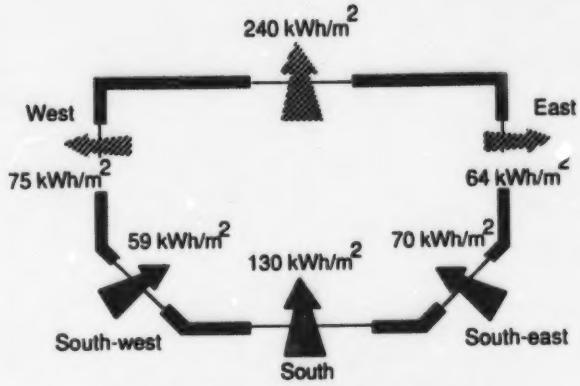


Fig. 9.4 Thermal breaks in metal frames



Net energy flows through double glazed windows at various orientations. Calculations assume averageToronto heating season.

Fig. 9.5 Window orientation and heat flows

9.2.3 Solar Performance

Windows may be the source of net energy gains or losses to the home depending on their location. A complete assessment of existing windows will include a review of their distribution in the house envelope with a view to maximizing potential solar gains (up to a point) and minimizing summer cooling loads.

South-facing windows offer the best solar performance. Windows located within 30 degrees of south also offer significant net energy gains. East and west windows usually show a net energy loss over the heating season, unless they are high-performance windows, and are difficult to shade in the summer. North-facing windows show the greatest energy losses. (Figure 9.5)

In determining window area for new super-insulated housing, it has been found that a south-facing glass area which is 6% to 9% of the total floor area is most appropriate (Figure 9.6). A house built with standard construction materials can accommodate the solar gains from this size of glazing area without excessive temperature swings or overheating.

The south-facing glass area should comprise 50% of the total window area of the house with most of the balance located elsewhere. North and west facing windows should be avoided or minimized wherever possible.

Window shading should be included as part of the solar performance review (Figure 9.7). Overheating will

South-facing glazed area should not exceed 10 per cent of the livable floor area of the house

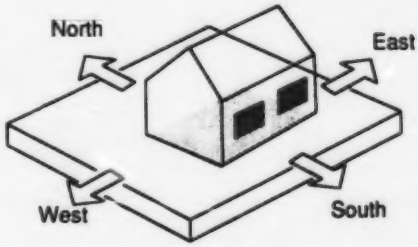


Fig. 9.6 South-facing window area

likely result if south glass area is increased without appropriate shading or if overhangs on existing windows are removed for the retrofit work and not replaced.

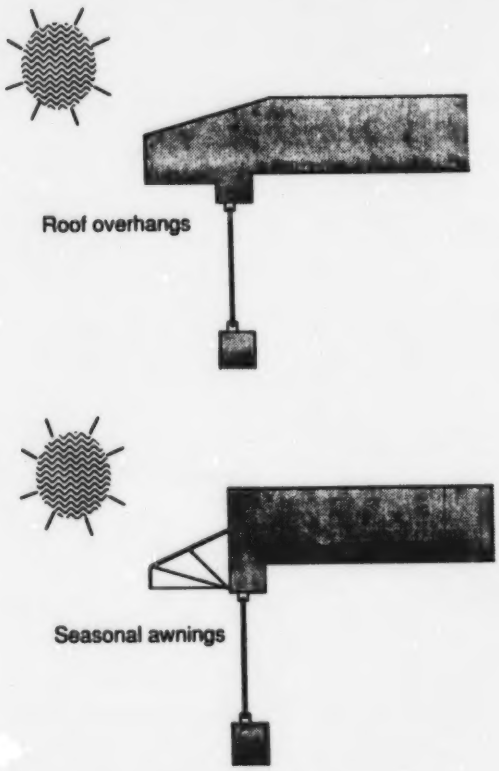


Fig. 9.7 Window shading options

9.24 Architectural Performance

Retrofit work provides the opportunity to replace or relocate individual windows as part of an upgrading of the appearance of the house. Major work will allow for an evaluation of the existing house windows relating to their role in providing natural ventilation, a view, daylighting and architectural features.

Major redesign of the location of the house windows should account for the role of the window as part of the natural cooling system of the house. Operable windows should be installed throughout the building to permit cross ventilation of the structure during the warmer months (Figure 9.8). As part of the renovation/retrofit, some of the windows might be relocated or replaced to allow for cooling breezes.

Rethinking window locations to maximize natural lighting and to take advantage of available views should be done as part of any major retrofit work. Changes to window locations can more easily be integrated while alterations are being made to the building envelope.

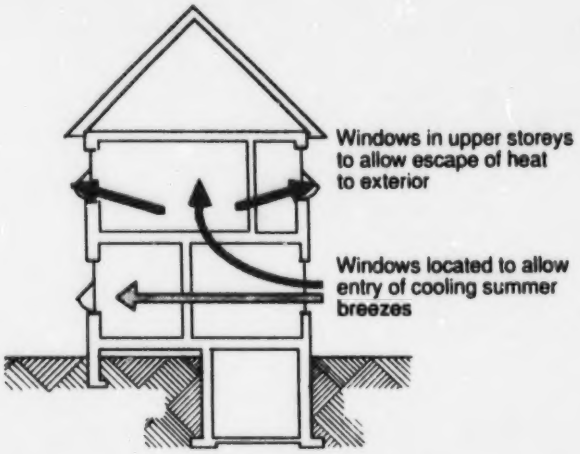


Fig. 9.8 Locating windows for ventilation

Finally, any major alterations to the facade of the house must account for the appearance of the building. Features of architectural or historical importance should be retained whenever possible, and consideration should be shown for the appearance of the building when ordering and installing new or replacement windows.

9.3 REPLACEMENT WINDOWS

Replacing windows offers several advantages over upgrading.

- Changes to window size and location may be made to improve solar performance or maximize design requirements such as daylighting.
- Replacement units may be chosen that are more energy efficient.
- New units and materials may be used which offer a longer service life and less maintenance.

9.3.1 Design Considerations

A balance is required when considering aesthetics, performance, and the cost of the planned work. While replacing older windows will generally improve performance beyond upgrading techniques – at least when using a high quality product – the price will often be too high to rationalize the purchase from energy considerations alone.

Complete replacement is most easily justified when some or all of the criteria below are met.

- There is structural damage to window sash, frame or rough stud opening.
- Existing windows provide inadequate daylighting, view or ventilation.
- The retrofit is part of other renovations involving a new floor plan which requires relocated windows or additional openings.
- The exterior retrofit is planned as part of a house 'face lift' to change the home's appearance and existing windows will not be compatible with the new finish.

When purchasing replacement windows, the contractor will want to consider the size of the unit, the window type, the type of glazing and frame materials, and the design.

Size

Where it is not essential to keep the exact size of the existing window, savings may be obtained by using stock sizes and enlarging or decreasing the rough opening to suit. The distribution of window openings on the house walls should be planned to optimize solar gains.

Type

Choice of window type will depend on where the window is located, ease of maintenance and whether it is required for ventilation. Fixed windows are preferred from an energy performance perspective as they are generally tighter. Of the opening types, awning and casement units (ones that swing open) are preferred as they permit a tighter seal when closed. Horizontal and vertical sliders are not generally recommended.

Glazing Materials

Selection of glazing materials for a new window will involve the following considerations:

- number of panes of glazing – minimum of double glazing;
- size of air space – minimum of 12 mm in a sealed unit;
- choice of glazing material – while ordinary glass is still most commonly used, many manufacturers now offer double or triple glazed units which include one sheet of glass or plastic with a heat reflective coating that boosts the window's insulating value;
- the method used to edge seal the unit;
- the optional use of gases in the sealed unit – a new technology is now offered by some manufacturers where the space between the panes of glass is filled with a low-conductivity gas in order to boost the effective R value of the unit.

Frame

The choice of design and materials for the sash and frame will affect the window's thermal performance as follows:

- Thermal conduction through the sash and frame may be minimized by using wood or vinyl frames or metal frames which incorporate a thermal break;
- Air leakage through the junction of opening sash and frame can be minimized through the design of the window and the use of high quality weatherstripping and closure hardware.

In addition to thermal performance, design considerations such as compatibility with the building's overall appearance will play a major role in window frame selection.

9.4 UPGRADING OPTIONS

There are two basic strategies for improving the thermal performance of windows: reducing air leakage and upgrading the insulating value of the glazing. The following section describes the various upgrading options and provides notes on their effectiveness.

9.4.1 Air Sealing (Figure 9.9)

This is the simplest and least costly of upgrading options. Four steps are involved:

- insulating and sealing the gap between the window frame and the rough opening;
- installing gaskets on all opening junctions between sash and frame;
- installing new hardware and closures to ensure that gaskets are properly compressed when the sash is closed; and
- sealing all junctions between glass and sash.

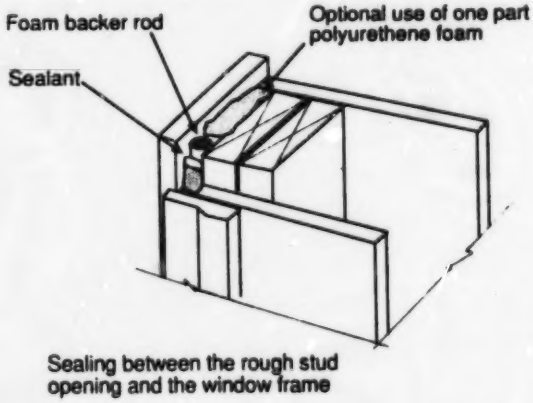

Foam backer rod
Optional use of one part polyurethene foam
Sealant
Sealing between the rough stud opening and the window frame

Fig. 9.9 Sealing around windows

While many of the other upgrading options address air leakage between sash and glass, there are few that also reduce the other two locations of air leakage, i.e., sash/frame and frame/rough opening.

A total retrofit of house walls will involve the removal and replacement of window trim to meet the new wall surface. **At the very minimum, the junction between the rough opening and the frame should be insulated and sealed to the wall air barrier while it is exposed.**

Air sealing will improve performance by reducing discomfort due to air leakage and drafts and by improving the operation and closure of the unit.

9.4.2 Replacement Glazing

This retrofit option involves replacing the existing glazing with a higher performance sealed unit. The replacement glazing may be installed in the existing sash or opening of fixed units or, where the sash is in poor condition, both sash and glazing may be replaced in the existing frame.

Replacement glazing will offer a wide variety of options for the homeowner. The contractor should be led by the design considerations relating to glazing performance as outlined in 9.3.1. The wide range of products available on the marketplace may require some additional research on the part of the contractor.

The major benefits to be gained from replacement glazing will include

- a reduction in air leakage around the window sash, which is associated with poor window performance;
- an improvement in the thermal performance of the window with an associated improvement in comfort levels for the homeowners; and
- reduced maintenance costs.

9.4.3 Add a Glazing

Additional glazing may be added to the interior of existing windows in two ways: a single lite may be added or, where depth of sash or frame permits, a sealed double-pane unit may be installed.

In both cases, the existing single glazing will become part of a permanent double window and the space between the new and existing glazing must be vented to allow the escape of any moisture allowed to get between the panes (Figure 9.10).

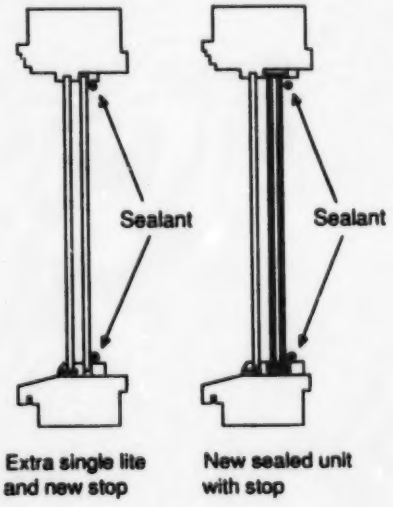


Fig. 9.10 Adding glazing

The effects of adding a glazing are the same as for replacing glazing. However, even with venting, there is the potential for condensation and associated scumming of the glass between the new unit and the existing glazing.

9.4.4 Interior Storms

Interior storms involve the installation of a seasonal transparent glazing over the interior of the existing window. A wide variety of products is available, ranging from disposable types of heat shrunk film (used for one season only) to durable products of rigid plastic or glass. The installation of interior storms will have the following beneficial effects:

- When installed over the junction between window frame and the wall, interior storms can reduce window air leakage.
- The insulating value of the window will be improved. With warmer surface temperatures on the inner glazing, and by reducing thermal bridging across the window frame, problems of excessive condensation will be reduced.

Some of the design problems which need to be addressed before purchasing interior storm windows include the following:

- Fixed storms will prohibit operation of the prime window for ventilation. With the addition of an extra stop, interior storms may be installed in sections to facilitate window opening.
- Limited styles and colours in the fastening strip which is attached to the wall or window trim may affect the architectural appearance of the window.

9.4.5 Exterior Storms

Exterior storms of wood or metal are a familiar building element. While exterior storms can improve the insulating value of windows, they should not be used to stop air leakage. The primary air seal should always be on the interior. For this reason, proper installation of exterior storms will involve provision for venting to the exterior.

In addition to these concerns, the installation of exterior storms will affect the following:

- Appearance of the storm may not suit the building's exterior.
- Condensation on the existing glazing will be reduced but condensation may occur on the storm glazing depending on the degree of air leakage through the primary window.

9.5 PLACEMENT AND INSTALLATION NOTES

Whether the house windows are replaced or upgraded, attention to detailing at the window opening is required. In order to provide maximum performance, the window frame must be connected to the wall air barrier. Further, to ensure durability of the wall and window materials, new flashing and weather barrier details need to be provided.

9.5.1 Placement

A total retrofit will result in thicker house walls. Existing windows which were formerly at the mid-point in the wall will now be located towards the inside or outside of the thermal envelope.

An exterior retrofit will place existing windows towards the inside of the wall. This offers several advantages:

- the window frame is on the warm side of the wall; and
- interior air flow across the glass is improved, resulting in a warmer pane and less condensation.

However, a deep exterior sill will need to be provided with proper flashing details in order to protect the wall materials and window frame from water damage (Figure 9.11).

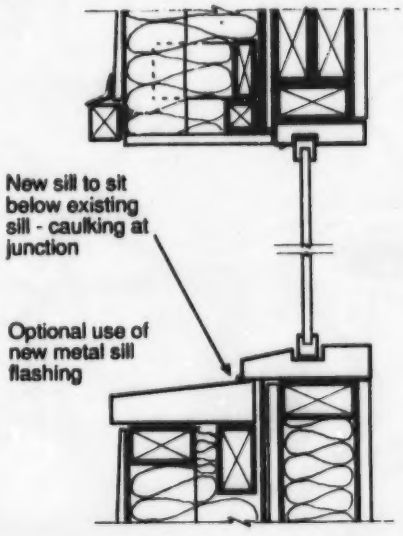


Fig. 9.11 Deep exterior sill

An interior retrofit will result in a window located towards the cold side of the envelope (Figure 9.12). With this arrangement there are other advantages:

- it is easier to provide weatherproofing on the exterior; and
- the deep interior sill is an attractive architectural feature.

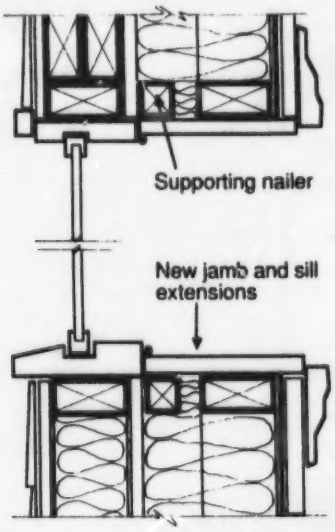


Fig. 9.12 Deep interior sill

However, depending on the insulating value of the glazing, the window may experience some condensation.

Replacement windows may be located towards the inside or outside of the retrofitted wall. For the reasons noted above, most replacement windows are placed towards the exterior. Since replacement windows will incorporate glazing with higher insulating values, condensation is not likely to be a problem. Where there exists concerns about condensation, the sills can be waterproofed to minimize any potential problems.

9.5.2 Installation Options

While the various upgrading options have been previously discussed, this section will focus specifically on ensuring a continuous link from the window to the new air barrier.

New Windows New windows can be located in the existing opening in a manner which provides a high level of airtightness. Whether the retrofit is being performed from the inside or outside of the house walls, the preferred options would involve providing a new liner for the window spanning the entire thickness of the wall. Once this liner has been installed and sealed to the air barrier, the new window can be installed at any location in the assembly and finished to meet the homeowner's requirements.

The major steps involved in this work would include the following:

- Remove any existing window trim or brick mould.
- Remove the existing window and frame.
- Install a 12 mm plywood liner which is sealed to the finished air barrier (Figure 9.13). When performing exterior work, the plywood is sealed to the polyethylene which laps over the existing rough stud opening. Interior retrofits would allow the polyethylene to be lapped over the plywood and sealed with acoustical caulking.
- The window can be located anywhere in the opening, although an exterior mounting is most conventional and will provide fewer weathering problems.

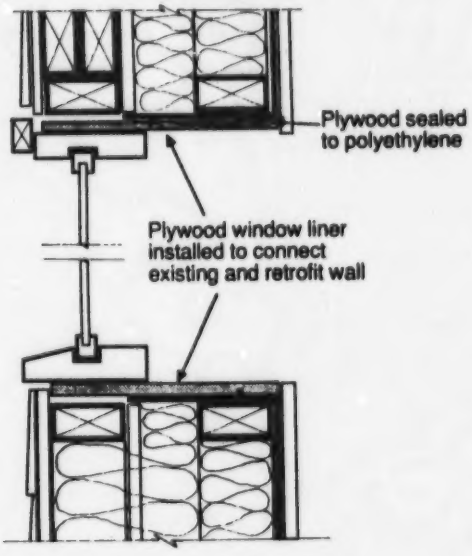


Fig. 9.13 Plywood liner

- Finishing on the inside could be either a drywall, wood or ceramic sill. Where a considerable exterior sill is desired, the contractor should consider providing metal flashing over the sill (Figure 9.14).

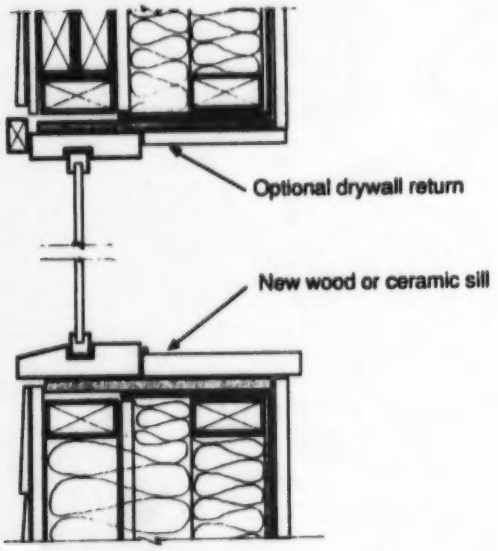


Fig. 9.14 New interior finishes

Polyethylene Wrap The other approach to air sealing a window involves wrapping it in a polyethylene sleeve before installation. The polyethylene sleeve can be sealed directly to the main air barrier on the house interior. It is most applicable as part of an interior retrofit. Stages of the job are illustrated in Figure 9.15.

- Remove the existing trim.
- Install a 300 to 400 mm sleeve of polyethylene around the window – caulk and staple to the outside of the frame, and provide overlaps at corners as illustrated.
- Install the window and stretch the polyethylene to the interior.
- Seal the polyethylene to the main wall air barrier.
- Install new sill and jamb extensions.

Existing Windows If the existing windows are being kept, it is still important to eliminate air leakage between the window frame and the rough stud opening. This can be accomplished whether retrofitting on the outside or on the inside by sealing the new air barrier directly to the existing frame. While the work is the same for interior or exterior sealing, slight differences in job sequencing may apply.

Exterior Retrofit

- When installing the polyethylene air barrier, a continuous seal to the window frame is required. This can be attained by caulking the poly to the face of the exposed frame and to the underside of the existing window sill.

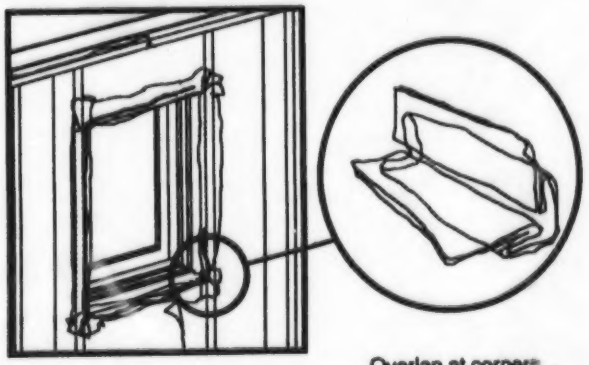


Fig. 9.15 Bagging windows

- Convective air loops might occur between the polyethylene and the house siding because of air pockets created by projecting sills or brick mould. The cause of the problem should be cut back or removed (Figure 9.16).

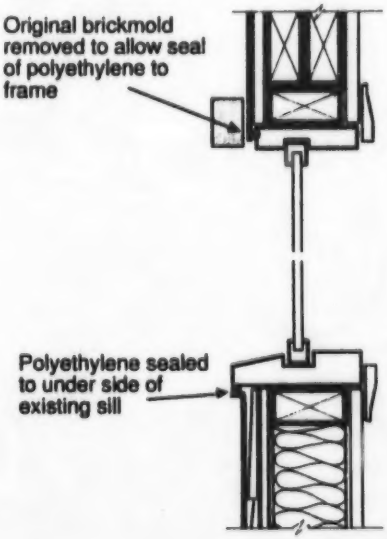


Fig. 9.16 Exterior air barrier detailing at windows

Interior Retrofit

- Existing window trim is removed.
- All framing and insulating is performed before the air barrier is installed. Rough frame openings must accommodate the new sill.
- The polyethylene which is laid over the entire opening is slit in an "X" shape from corner to corner and folds are sealed to the face edge of the window frame with acoustical caulking. Small pieces of polyethylene will be needed to seal the corners of the air barrier as it extends to the outside (Figure 9.17).
- New sill and jamb extensions should be fastened directly over the polyethylene.
- Drywall can be an acceptable air barrier as long as the junction between the window jamb and the drywall is properly sealed with a caulking or gasketing.

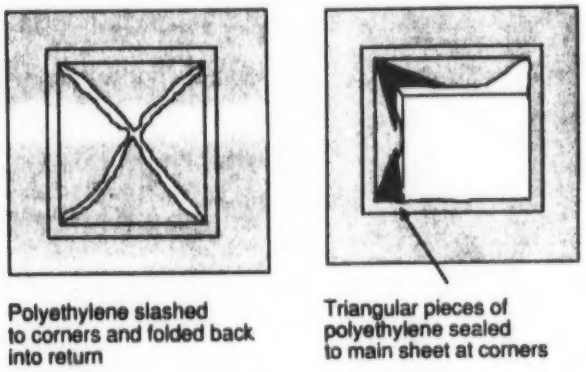

Polyethylene slashed to corners and folded back into return
Triangular pieces of polyethylene sealed to main sheet at corners

Fig. 9.17 Interior air barrier detailing at windows

10

INSULATING HOUSE ATTICS AND ROOFS

As part of major renovation and retrofit work, the reinsulation of the house attic or roof is important to the overall performance of the upgraded house. While some insulation may have been added to the house attic over the years, the total retrofit will incorporate higher insulation levels, improved airtightness, and control over moisture flow into the attic.

In the majority of cases, upgrading the house attic will prove to be one of the easiest components of the total retrofit. This is primarily due to the accessibility of most house attics and the fact that the reinsulation and airtightening can be performed in isolation from the living spaces of the house. As the attic is hidden from view there will be no concern for finishing details such as colour of paint, quality of miter joints and screw pops in drywall.

However, many types of attics or roofs will prove more difficult to reinsulate. Where access is restricted or impossible (cathedral ceilings, flat roofs, etc.) the options are reduced. This chapter will look at the thermal upgrading of both accessible and inaccessible attics. The major focus of this chapter is reinsulating the attic from the interior of the house. While the issues and techniques relating to exterior reinsulation of the house roof will be detailed, this approach is assumed to be relevant in only a small number of cases.

10.1 REQUIREMENTS OF AN EFFECTIVE ATTIC RETROFIT

As with other aspects of the total retrofit the reinsulation of the house attic should address the following issues:

- **Reduce conductive heat losses** by allowing for high insulation levels throughout the house attic, and by minimizing thermal bridging.
- **Reduce heat losses by air leakage** by effectively sealing all potential air leakage routes from the house interior.
- **Reduce water vapour flows into the attic** through the incorporation of an effective vapour barrier in conjunction with good air sealing.
- **Allow for ventilation of the attic** in a controlled and even manner.

10.1.1 *Reducing Conductive Heat Losses*

The successful installation of insulation depends on both the quantity of insulation, and the manner in which the insulation is installed. Where access to an attic is limited, the contractor will want to consider the use of blown-in materials. For accessible attics, blown-in, poured, or batt insulation can be installed with equal effectiveness. Best performance of the newly installed insulation will result from careful workmanship:

- providing even coverage of the insulation throughout the attic, ensuring adequate coverage over the top of any framing members;
- insulating over the top of wall top plates, attic hatch framing, etc.;
- ensuring that the insulation is installed at the density recommended by the manufacturer;
- ensuring that the insulation is installed without major air gaps; and
- ensuring that outside air is prevented from circulating through the insulation by using proper baffling at the soffit.

10.1.2 *Reducing Air Leakage*

Air leakage into the attic or insulated roof can result in excess heat losses and the deposition of moisture into the insulated cavity. On account of the stack effect, air sealing of the house attic is especially important. The common air leakage paths into the attic include the following:

- the junction of wall plates;
- ceiling electrical fixtures and wiring penetrations;
- plumbing vent stacks; and
- around chimney penetrations.

For an effective, long lasting reinsulation job, all potential paths for air leakage from the heated area of the house into the attic should be carefully sealed. *Air Sealing Homes for Energy Conservation*, provides detailed information on the air sealing of house attics (see Appendix B).

This manual on whole house retrofit outlines techniques which involve the installation of sheet air barriers. As part of a total retrofit, the contractor will attempt to establish continuity of the air barrier from the walls below to the air barrier being installed in the attic. While installing continuous sheet materials is prohibited by the rafters, careful installation can result in the top plate of the wall serving as the air barrier junction. The use of rigid board materials as the air barrier has been previously discussed and is particularly relevant to attics and ceilings without penetrations.

10.1.3 *Preventing the Movement of Water Vapour into the Attic*

Proper air sealing of the attic will result in the prevention of the largest source of water vapour entry into the attic. The contractor will still want to install a vapour barrier to prevent the entry of vapour by diffusion. This vapour barrier may be provided by sheet materials such as polyethylene or by the application of a painted vapour barrier material. The application, over time, of several coats of an enamel paint will often provide acceptable vapour barrier characteristics. When air leakage into the attic has been properly restricted, continuity of the vapour barrier is less important.

10.1.4. *Allowing for Attic Ventilation*

Attic ventilation is required to ensure removal of any water vapour which has entered the attic space and to ensure removal of heat buildup in the warmer months of the year.

Ventilation requirements, as stipulated in the National Building Code of Canada, ensure that the water vapour entering the attic is adequately dispersed to the outside. A properly installed air barrier and vapour barrier will greatly reduce the likelihood of water vapour entering the insulated cavity. While too little attic ventilation can lead to problems, too much ventilation can impair the performance of the retrofit work. Excessive ventilation, especially when provided by power fans, can result in the entry of more moisture into the attic than would be the case under normal operating conditions. This might lead to a more significant buildup of frost and ice, and would definitely lead to greater heat losses.

10.2 DECISION-MAKING

The approach taken by the contractor and homeowner will be influenced by the condition of the existing roof and by the costs of the various measures. In the vast majority of cases, the easiest and least expensive means of upgrading the performance of the existing ceiling/roof is to reinsulate and seal from the interior. Where the roof structure is in good shape and is relatively accessible, working from the interior will prove to be the wisest and most economical choice. Exterior reinsulation of the house attic and/or flat roofs can only be justified as part of major renovations. An attic insulation job costing several thousand dollars which saves less than one hundred dollars annually will be difficult to justify to the client.

This chapter highlights techniques which might be employed in providing high insulation levels in conjunction with improved airtightness. Section 10.3 provides an overview of reinsulation procedures for an accessible attic, the most common technique for reducing heat loss through the upper levels of the house. Section 10.4 addresses the various techniques employed in reinsulating flat roofs and cathedral ceilings from the interior where access to the cavities is restricted. Finally, exterior reinsulation techniques are detailed in Section 10.5. As part of an exterior retrofit this approach can result in exceptional levels of airtightness.

10.3 ATTIC REINSULATION

Most literature has addressed the subject of reinsulating accessible attics without stressing the importance of simultaneously installing an effective air barrier. As mentioned above, any air leakage entry locations to the attic must be effectively sealed. The contractor will have the option of air sealing the ceiling either from above or from below. In most instances, the work will provide a vapour barrier at the same time as providing airtightness.

A continuous air barrier and vapour barrier can be installed on the underside of the ceiling joists as part of a major renovation (Figure 10.1). In most instances this will involve the use of sheet polyethylene, although rigid board material can also be employed. Where rigid materials are used as an air barrier, the vapour barrier can be supplied either by the material itself or by painting over with a vapour barrier paint.

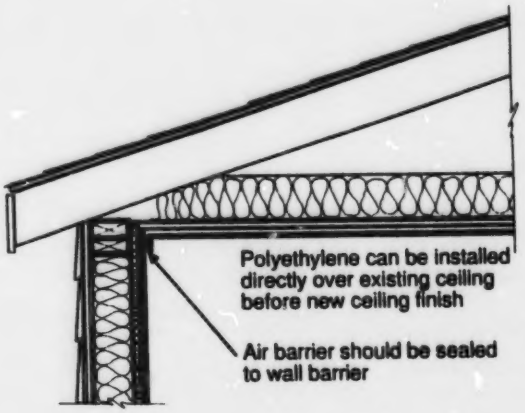

Polyethylene can be installed directly over existing ceiling before new ceiling finish
Air barrier should be sealed to wall barrier

Fig. 10.1 Installing ceiling air barrier

Providing a good seal to any given room will pose no problem. However, in an ideal situation the air barrier will be continuous across the entire ceiling. Where the house is being gutted or where major work is being carried out, a continuous air barrier can be installed in a relatively simple fashion. Continuity of the barrier past the top plate of partition walls would involve the same techniques used for interior wall retrofits as presented in Section 8.2 (Figure 10.2).

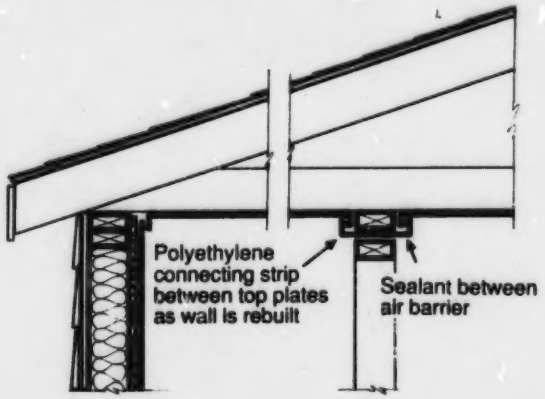


Fig. 10.2 Sealing at partition walls

Where the planned renovation work is less ambitious, the new air barrier could be sandwiched between the existing ceiling and a new layer of gypsum board. Detailing for an airtight seal over partition walls will require working from above with connecting strips of polyethylene or extruded polystyrene (Figure 10.3).

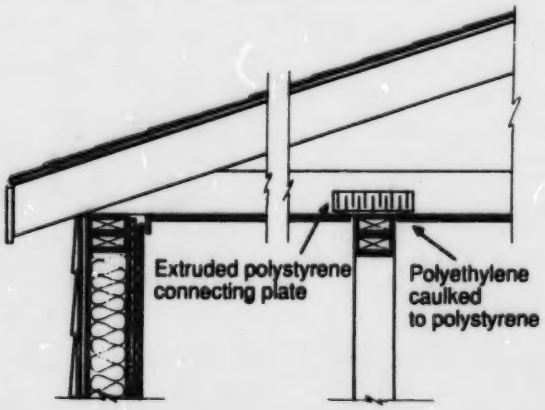


Fig. 10.3 Sealing over partition walls

When the air and vapour barrier is on the underside of the ceiling joists, attic insulation can be installed without regard to the 1/3 - 2/3 rule for vapour barrier placement. It will prove to the long-term advantage of the homeowner to install high levels of insulation in keeping with the total retrofit approach.

An alternative approach to the installation of the air barrier from the underside of the ceiling joists involves the installation of a sheet of polyethylene directly over the existing ceiling joists from the attic side. By installing the polyethylene to span the entire attic, a good air and vapour barrier can be attained (Figure 10.4). This practice has the advantage of allowing all the work to be performed from inside the attic with only a minor amount of disruption to the house occupants. Secondly, this technique allows for the existing attic insulation to be maintained — unless it has been subject to major deterioration.

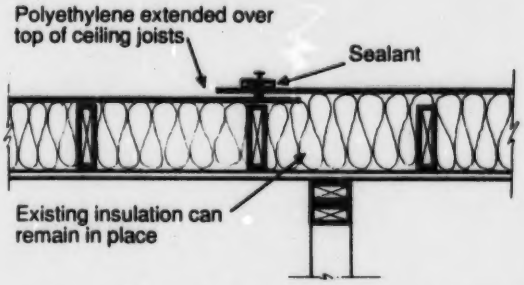


Fig. 10.4 Installing the air barrier over the joists

If problems are to arise with this technique, they will relate to the difficulty in sealing the sheet material to the wall top plate. At the soffit of the attic it may prove easier to use extruded polystyrene as the connecting strip between the attic air barrier and the top plate of the wall. As illustrated in Figure 10.5, the rigid board insulation should extend from the top of the wall toward the centre of the attic, to a distance which allows for the later addition of adequate insulation at the eaves. At that point, a second strip of rigid board material is required to act as a junction to the polyethylene. Seams between the materials should be caulked to ensure a good seal.

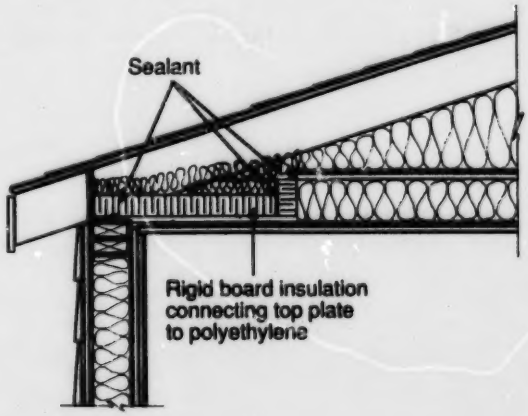


Fig. 10.5 Soffit detailing

After the polyethylene has been installed over top of the joists it should be sealed at seams and to the attic hatch opening (Figure 10.6) using a combination of caulking, staples and battens to secure the seams and edges. Blown or batt insulation will need to be added to a level equivalent to at least twice the RSI value of the existing insulation, meeting the requirements of the 1/3 - 2/3 rule as described in Chapter 2 (Figure 10.7). Maintaining soffit ventilation may require the use of baffles to prevent the insulation from blocking the soffits. To complete the job, several layers of rigid board insulation should be fastened to the back of the attic hatch and the hatch should be weatherstripped to provide a tight seal.

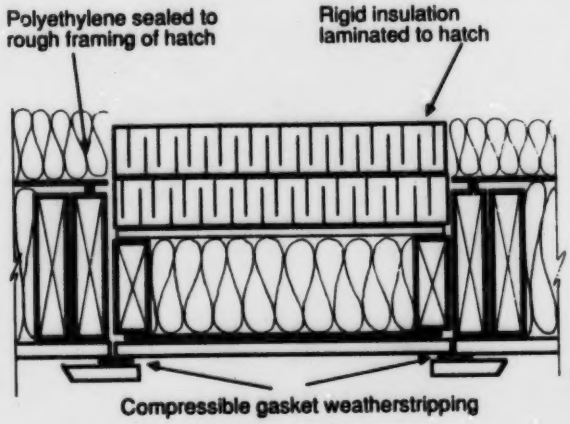

Polyethylene sealed to rough framing of hatch
Rigid insulation laminated to hatch
Compressible gasket weatherstripping

Fig. 10.6 Detailing at attic hatch

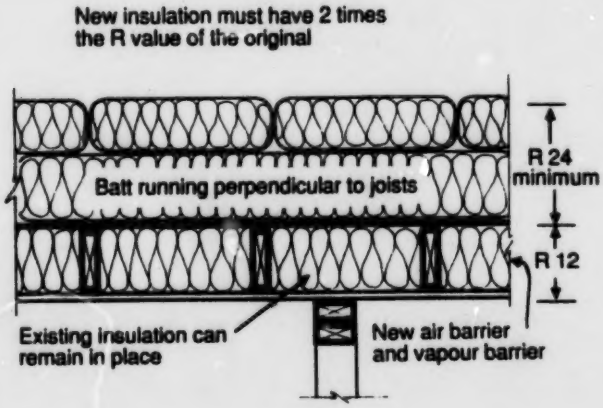

New insulation must have 2 times the R value of the original
Batt running perpendicular to joists
R 24 minimum
R 12
Existing insulation can remain in place
New air barrier and vapour barrier

Fig. 10.7 Locating the air barrier

An alternative to the work involved in providing a good seal to the attic hatch would involve relocating the hatch to the exterior of the attic. This can most easily be done by installing a new hatch in the gable end of the attic which would be accessible from the exterior.

10.4 INSULATING CATHEDRAL CEILINGS AND FLAT ROOFS

Cathedral ceilings and flat roof assemblies present a greater challenge to the contractor attempting to install higher levels of insulation. The major problem with these types of roofs relates to the limited space available - generally the dimension of the ceiling joists or rafters. The contractor not only needs space to allow for insulation but also space for ventilation of the roof.

Most building codes will require that a minimum ventilation space of 75 mm be provided between the insulation and the underside of the roof sheathing. This means that the thickness of insulation which can be installed in the cavity would be 75 mm less than the dimension of the lumber (Figure 10.8). For instance with roof joists of 38 x 235 mm a maximum of 185 mm of insulation could be installed – equivalent to a batt insulation of RSI 4.9. Smaller dimensioned lumber would further restrict the insulation levels.

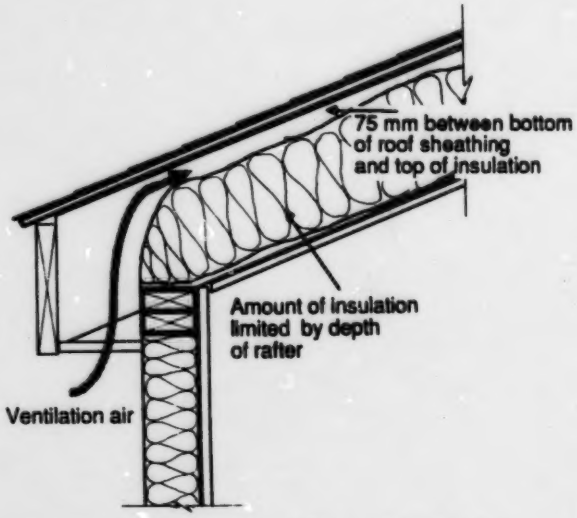

75 mm between bottom of roof sheathing and top of insulation
Amount of insulation limited by depth of rafter
Ventilation air

Fig. 10.8 Providing ventilation of cathedral ceilings

To improve the thermal performance of this roof type will involve expanding the size of the cavity. Reinsulating from the exterior is addressed in Section 10.5, and is most easily justified as part of major repairs or restoration of the existing roof deck. From the interior of the house, two different options can be considered:

- strapping and/or rigid board insulation; and
- extending the rafter cavity.

10.4.1 Strapping and/or Rigid Board Insulation

One of the easiest means of adding insulation is by applying the new insulation directly over the existing ceiling from below. This option means that the existing ceiling finish can be kept intact, but it does not allow access to the existing cavity.

Adding insulation to the underside of the existing ceiling can be done by directly applying rigid board insulating materials, or by strapping the ceiling down. A polyethylene air and vapour barrier can be installed at any point in the new assembly as long as it maintains the 1/3 – 2/3 rule with twice the insulating value on the cold outside of the barrier. Installing rigid board insulation directly to the ceiling would follow those fastening techniques presented in 8.2.3. The contractor will want to make sure that proper techniques are used:

- the rigid board is mechanically fastened directly to the roof structure (Figure 10.9);

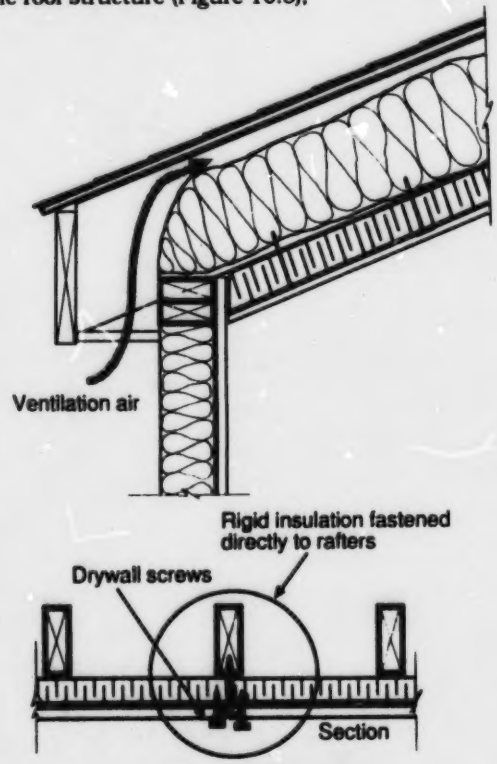


Fig. 10.9 Fastening rigid insulation

- adequate nailing surfaces are provided for the new wallboards or ceiling finishes (Figure 10.10);
- the boards are tightly fitted to reduce any convections;
- if the rigid board is doubling as the air barrier and vapour barrier, seams in the material are well sealed; and
- any electrical fixtures are safely extended to the depth of the new finished ceiling.

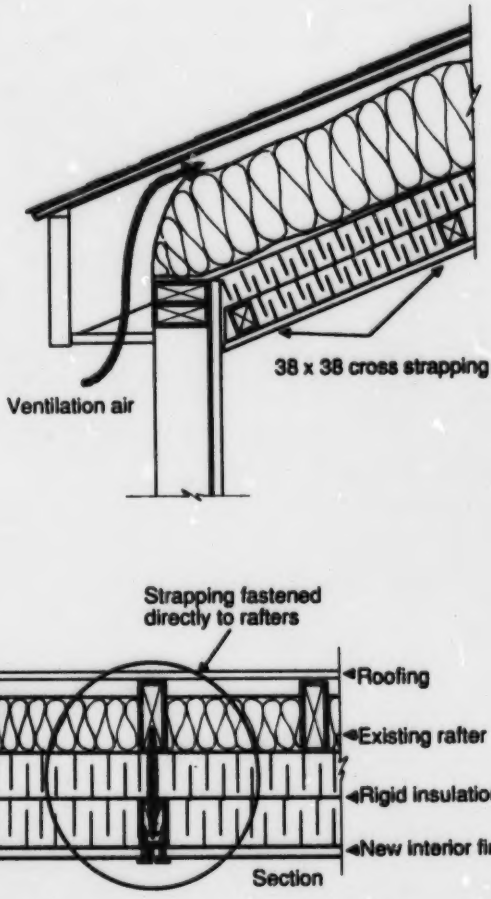


Fig. 10.10 Strapping and rigid insulation

Where the contractor wants to add a large thickness of rigid board to the underside of the ceiling, cross strapping might be required. The cross strapping can allow for a nailing surface for the finished ceiling while providing support to the rigid board insulation. Several different configurations of strapping and rigid board materials are illustrated in Figure 10.10. The contractor must appreciate that each layer of cross strapping involves another pass at the ceiling.

Cross strapping can be installed to accommodate batt insulation. While material costs for this approach will be less than for those using rigid board materials, it will prove more difficult to add significant levels of insulation. If cross strapping with 38 x 64 mm material or larger, it could be difficult to nail a strong joint. A solution would be to pre-nail the strapping and fastening with long nails (Figure 10.11). One further consideration when using batt insulation overhead is that the insulation will fall, unless the strapping has been installed at the proper centres.

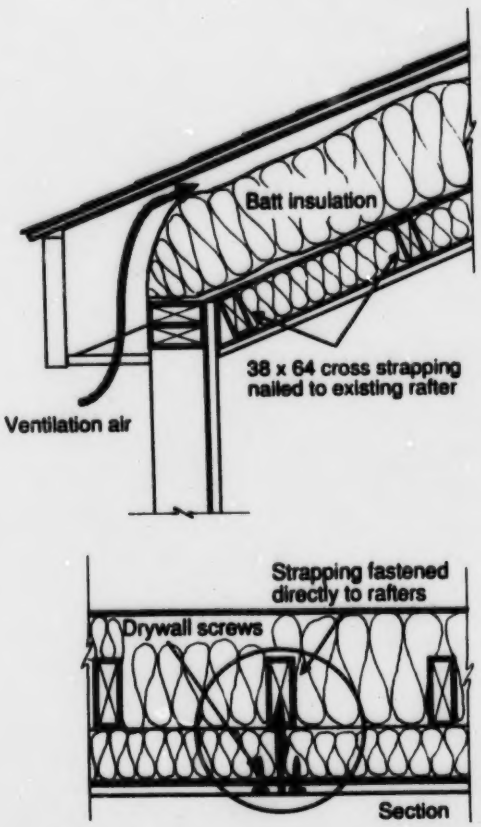


Fig. 10.11 Strapping and batt insulation

10.4.2 Extending the Rafter Cavity

In many cases, the existing ceiling or rafter cavities can be extended into the living area to allow for the addition of greater amounts of insulation. Where the disruption to the house is permitted, and where the homeowner does not mind reducing the height of the existing ceiling, a dropped rafter cavity can prove an acceptable option.

The techniques which can be used will be determined by the shape and structure of the existing roof or ceiling. Where the roof joists have been installed at standard centres, the rafters can be extended in the same plane. However, where the existing rafters are at random centres it may prove easier to install the new roof perpendicular to the existing rafters.

Working with the existing rafters is the easier of the two options. The new rafter can be gussetted directly to the rafter above at a height which accounts for the amount of insulation required and the neccessary air space below the roof sheathing. The new rafter can be a 38 x 89 mm as it will only carry the load of the new ceiling. The new rafter can be tied to the existing using either 38 x 89 mm material or 12 mm plywood (Figure 10.12). The plywood, especially when installed on both sides of the rafters, can add extra rigidity to the assembly. The blocking or plywood should be cut to a standard length to allow for easy placement of the new rafters at a location parallel to the existing rafter.

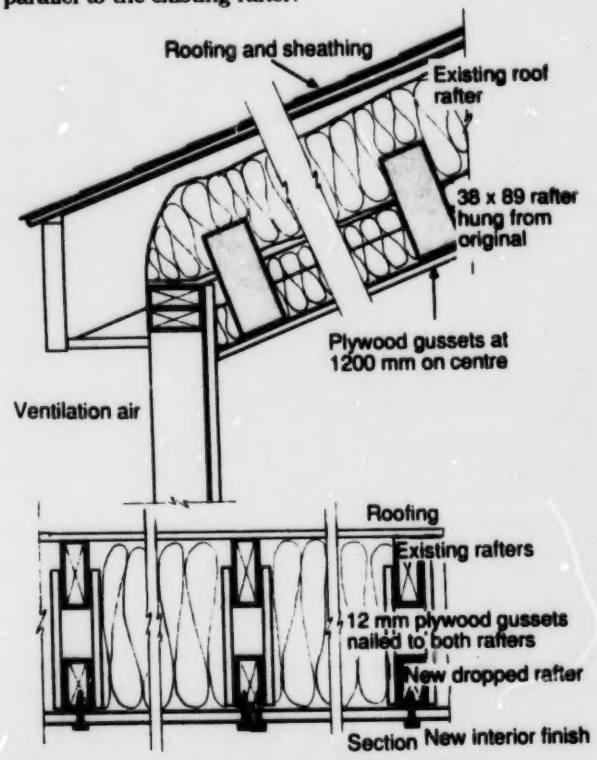


Fig. 10.12 Extending the rafter cavity

When the rafter extensions have been completed, new insulation is added to the cavity. The new batt insulation should be installed in a manner which ensures that continuous soffit ventilation is provided. If the insulation is to be compressed into the cavity, the contractor might consider running chicken wire or some other material at a location in the cavity which stops the insulation from being pushed against the roof sheathing (Figure 10.13). To prevent excessive air movement between the two rafters, additional scraps of batt insulation could be installed, or pieces of rigid insulation could be installed between the two rafters (Figure 10.14). The new air barrier can then be installed on the underside of the rafters before installing the new ceiling.

Where the rafter centres do not permit the dropping of the rafter as explained above, installing new rafters perpendicular to the originals will make finishing the job easier. If considering this approach, the contractor will need to provide good support from the old rafters to the dropped rafter. This may be most easily done using 38 x 89 mm blocking which extends from the existing rafter to the location of the new rafter (Figure 10.15). The new extended rafters can be placed at 600 mm on centre to minimize

labour and material requirements. While this technique may require more work than that outlined above, by allowing for a new layer of insulation running at a perpendicular to the existing cavity, convective air movements and thermal bridging can be reduced.

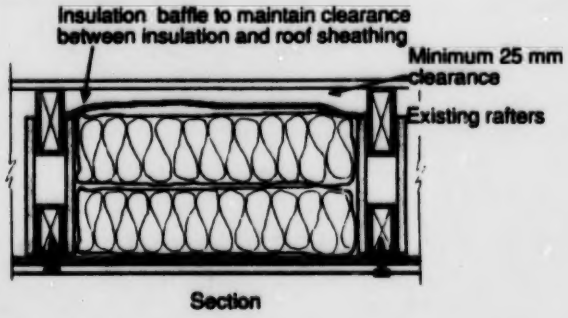

Insulation baffle to maintain clearance between insulation and roof sheathing
Minimum 25 mm clearance
Existing rafters
Section

Fig. 10.13 Maintaining ventilation

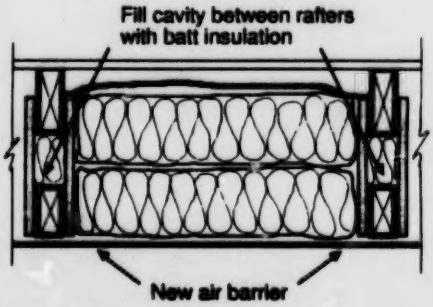


Fig. 10.14 Minimizing convective movements

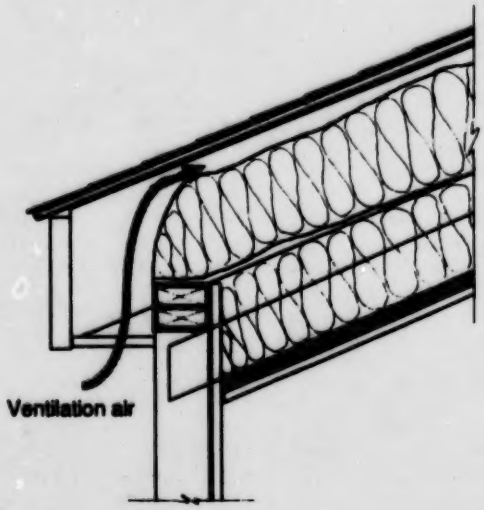


Fig. 10.15 Framing new interior rafters

If the dimensions of the room permit, the new rafters could be installed independent of the existing roof by supporting the new rafters from the walls. This could be accomplished by nailing a plate to the walls and either toenailing the rafters to the plate or using joist hangers for support (Figure 10.16). If the span were too great for 38 x 89 mm material, intermediate supports could be easily provided between the new and existing rafters.

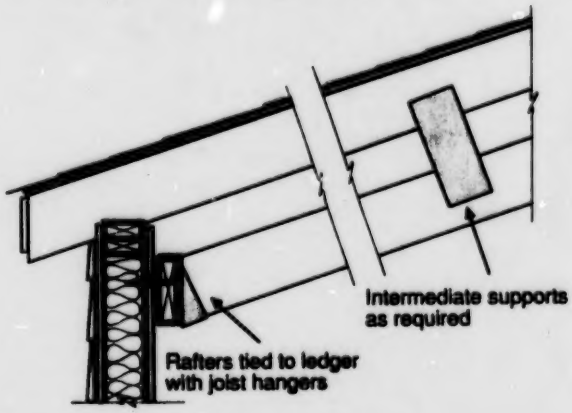


Fig. 10.16 Dropped ceiling rafters

10.5 EXTERIOR ROOF RETROFIT

As part of planned structural or aesthetic alterations to the house roof, major retrofit work can be performed from the exterior. While these techniques can result in superior thermal performance, especially when done in conjunction with an exterior retrofit of the house wall, the cost of the work can only be justified when the energy upgrade is a secondary consideration. For an average house, the cost of exterior retrofit work may approach several thousands of dollars. This will include reshingling, installing new sheathing, replacing eavestroughing, soffits and fascia, as well as disposal costs and haulage, and finally the costs of the installed insulation. It is apparent that few of these items could be considered as directly associated with the energy conservation aspect of the work.

Even when performing major alterations to the existing roof, exterior retrofit techniques may not be the best alternative to upgrading energy performance. Wherever improved air tightness and the required levels of insulation can be installed into the existing roof structure, it is recommended to follow the techniques outlined in Section 10.3. Exterior roof retrofits may be the preferred option where

- the interior finish of the existing ceiling is worth retaining; and
- plans call for an upgrading of the existing attic into usable space.

Two basic techniques for the exterior retrofit of roofs can be employed. The first technique employs insulation methods conventional to commercial installations, the use of rigid board insulation in conjunction with different roofing materials. The second technique described involves framing a new roof assembly directly over the existing house structure. Both techniques can result in greatly improved airtightness and increased insulation levels. While the specific installation will vary depending on the technique employed, job preparation considerations will be the same for both types of retrofit. The main considerations will include the following:

- removal of existing roofing materials;
- alteration to existing soffit and fascia;
- application of new air barrier and vapour barrier; and
- extension of roof flashings, etc.

Exterior retrofitting of house roofs requires careful timing on the part of the contractor. Where the existing roof is being lifted and flashings are being altered, the house will be susceptible to rain damage. Similarly, some of the new materials being used can be affected by rain damage. The contractor might consider doing one half of the roof at a time to condense the time period over which damage might occur. Tarps and/or other protective materials should always be close at hand.

The contractor will need to analyse the existing roof for the shape of the existing roofing material and the ability of the roof structure to bear the loading of a new roof membrane. In the vast majority of cases it will prove advantageous to **strip the existing roofing materials**. This has the advantage of providing a cleaner, more even surface for the latter work, while at the same time reducing an excessive dead loading on the roof structure. The flat surface which can be provided will minimize any convection occuring between the roof sheathing and the air barrier, thereby enhancing the performance of the retrofitted assembly.

The contractor will need to **assess the detailing at the soffit and fascia of the house**. Where the exterior roof retrofit is being performed in conjunction with exterior wall retrofit strategies, the contractor will have the option of providing a continuous thermal wrap from wall to roof. This may require some alterations to the existing rafter tails to ensure that the air barrier and vapour barrier stay inside of the dew point location (Figure 10.17). Where the retrofit is being performed in isolation from any wall retrofit work, the contractor will still want to detail enlarged or altered fascia at the end of the new roof.

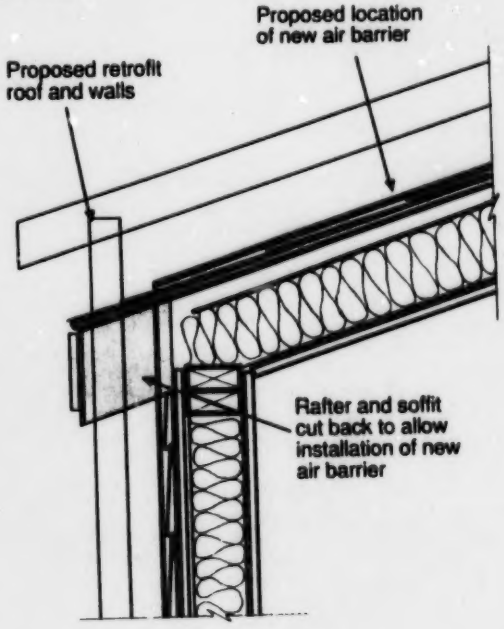

Proposed location of new air barrier
Proposed retrofit roof and walls
Rafter and soffit cut back to allow installation of new air barrier

Fig. 10.17 Cutting back the roof

As part of a total retrofit package, the contractor will want to attempt to **maintain continuity of the air barrier from the walls below to the retrofitted roof**. This can be accomplished where an exterior retrofit of the walls is being performed at the same time as the roof retrofit. The use of sheet polyethylene materials over the existing roof can pose major safety problems. If polyethylene is used as the air barrier, surfaces for walking and working

must be provided to the workers. Where an exterior roof retrofit is being performed at the same time as an interior retrofit of the house walls, continuity of any sheet air barrier material will prove difficult. Figure 10.18 illustrates several options for integrating an exterior and interior air barrier.

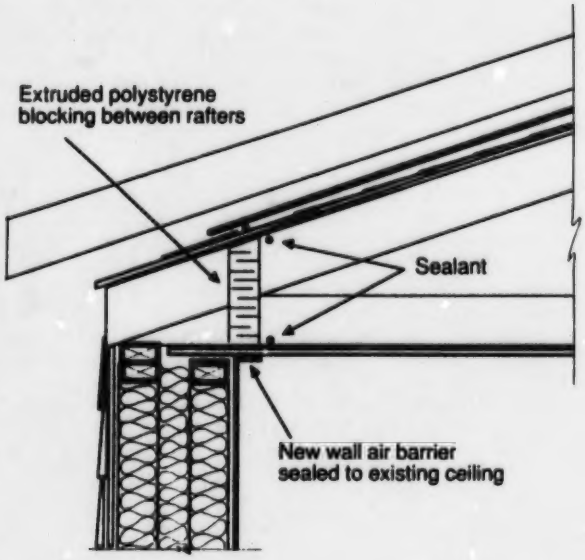


Fig. 10.18 Integrating roof and wall air barrier

Whenever major alterations to an existing roof are being undertaken the contractor must consider first and foremost sound waterproofing and drainage techniques. When the thickness of the roof is being altered, **new flashings** will be required for chimneys, stoves, plumbing stacks, electrical mast heads, etc. The retrofitted roof will be equipped with a new membrane — either new shingles, roof tiles, roll roofing or a built up membrane. In all cases the installation of the new roofing material must follow good building practices.

10.5.1 Rigid Board Insulation

Rigid board insulation can be installed directly over the existing roof sheathing. Reinsulating with rigid board insulation has the advantage of employing higher RSI-value materials, thus requiring a smaller increase in the roof thickness. Rigid board retrofit techniques may also be less labour intensive than those techniques requiring new framing. As a general rule, the cost of rigid board materials will prove more costly than fibreglass or loose fill materials.

An air barrier and vapour barrier can be installed by one of two means when installing rigid board insulation. The boards can be laid directly over sheet polyethylene as described above, or low permeance rigid board materials can be installed with the joints in the material taped to prevent air leakage. The latter alternative would be the preferred option since the risks associated with walking on the polyethylene are removed. The air barrier should be located as close to the existing roof as possible to minimize the risk of condensation. Where multiple layers of rigid insulation are being installed, the bottom layer of insulation should be taped as the air barrier.

The choice as to which insulation material to employ will be influenced by the following considerations:

- level of insulation required;
- permeability of the material;
- compressive strength of the insulation boards;
- preferred fastening techniques;
- compatability with the new roofing material; and
- installed cost of the material.

Manufacturer's literature should be carefully analysed to ensure that the material meets the intended application and that the contractor is familiar with the installation procedure.

In the majority of cases, providing higher levels of insulation will require that the rigid board insulation be installed in more than one layer. This will mean that intermediate fastening techniques should be employed to provide a firm base for the roof sheathing. The system employed must be designed to provide ventilation of the space between the rigid board insulation and the sheathing. The ventilation space will not only allow for venting of any moisture, but will prolong the life of the roofing material by cooling the underside during the warmer months.

The loading of the new roof must be transferred evenly to the existing roof structure. If the insulation material has a compressive strength lower than the local design roof load, intermediate support members will be required to bear the load of the roof. Any major changes to the loading pattern of the roof must comply with local code stipulations and may require structural alterations.

In most cases, the use of purlins over the insulation material will prove the best alternative. The purlins can provide a strong base for the roof sheathing while allowing for cross ventilation of the roof (Figure 10.19). Depending on the roof loading and design of the retrofitted roof, the purlins will be installed at either 400 mm or 600 mm centres. Where the wider spacing is employed, 'H' clips or blocking are needed at mid-span to support the roof sheathing. Detailing at the roof soffit must account for unobstructed air flow while preventing the access of insects, birds, and rodents.

Detailing at the soffit and fascia of the retrofitted roof may change to accommodate the horizontal ventilation of the new roof assembly. The contractor will need to pre-plan the construction so that adequate nailing surfaces are provided for finishing details. Finished roofing will follow conventional practices, using good flashing and waterproofing details. The type of roofing employed will be most influenced by the slope of the house roof and the preferences of the roofing contractor and will seldom be influenced by energy-related issues.

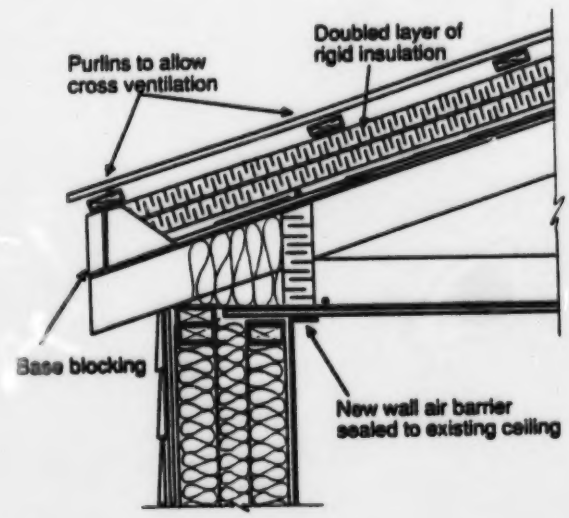

Purlins to allow cross ventilation
Doubled layer of rigid insulation
Base blocking
New wall air barrier sealed to existing ceiling

Fig. 10.19 Integrating roof and wall air barrier

10.5.2 New Roof Framing

A new roof structure can be framed on top of the existing roof framing to accommodate new glass fibre batt insulation. The use of batt insulation will generally reduce material costs, but involves the construction of a thicker roof assembly. The amount of insulation added to the new roof is only limited by the framing techniques employed. The incorporation of a new frame roof on top of the existing roof will add to the dead load characteristics of the assembly, which may, in some cases, require some structural analysis. As part of planned renovation work this technique can result in greatly improved roof performance.

The installation of a new frame wall will be done in conjunction with the installation of a polyethylene air and vapour barrier. Where the air barrier is to meet with its counterpart on the exterior walls, some preparatory work will be required. The tails of the existing rafters can be cut back flush to the face of the existing house walls (Figure 10.20). This will allow the polyethylene to run continuously over the roof.

To provide a working surface for the crew, and to hold the polyethylene in place, strips of plywood should be laid over the material. These strips should be fastened vertically and should be located over every second or third rafter.

The loading of the new roof must be spread evenly over the existing house structure. The best means of constructing the roof involves the installation of purlins spanning the length of the roof. In most cases three purlins will be required: at the base, the mid-point and the roof peak (Figure 10.21). In areas of heavy snow loads, or where the contractor is not certain of the strength of the existing roof, span charts should be consulted to ensure that the oad of the roof is adequately supported. The size of the purlins should be determined by the amount of insulation required for the new roof. The purlins can be fastened to the existing roof structure in a variety of means as illustrated in Figures 10.21 and 10.23.

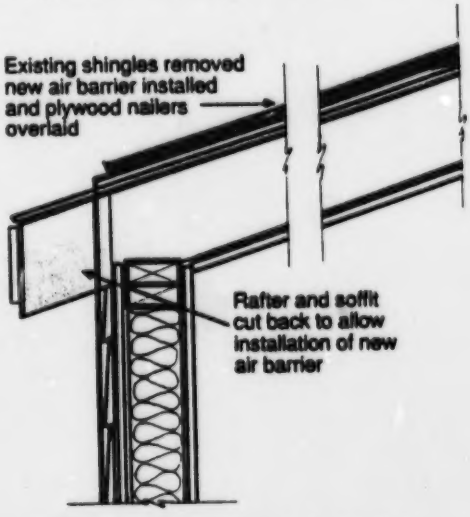

Existing shingles removed new air barrier installed and plywood nailers overlaid
Rafter and soffit cut back to allow installation of new air barrier

Fig. 10.20 Installing the new air barrier

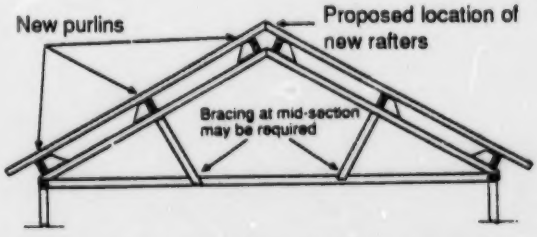


Fig. 10.21 Locating purlins for the new roof

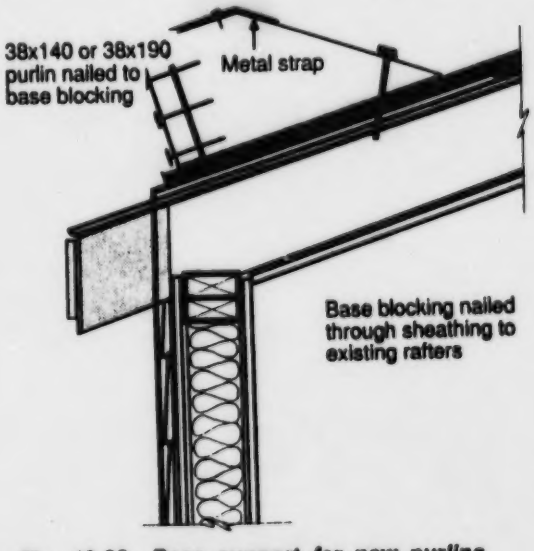

38x140 or 38x190 purlin nailed to base blocking
Metal strap
Base blocking nailed through sheathing to existing rafters

Fig. 10.22 Base support for new purlins

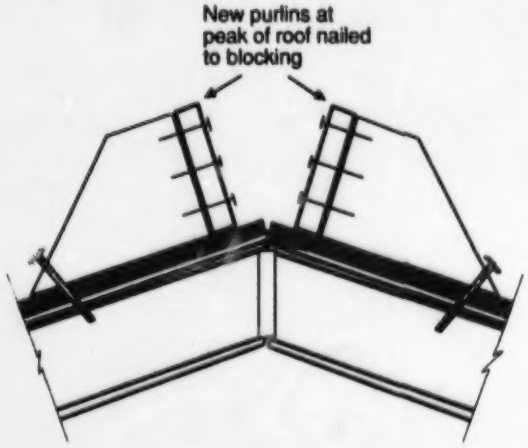


Fig. 10.23 Peak support for new purlins

Once the purlins have been installed, the new rafters can be located to span from the eaves to the ridge (Figure 10.24). Detailing of the rafter ends must accomodate the design of the new soffit and fascia. The rafter dimensions and centres can be determined from span charts, but will usually allow for 38 x 89 mm or 38 x 140 mm lumber at 400 mm or 600 mm centres. The centres must allow for standard-dimensioned insulation and plywood.

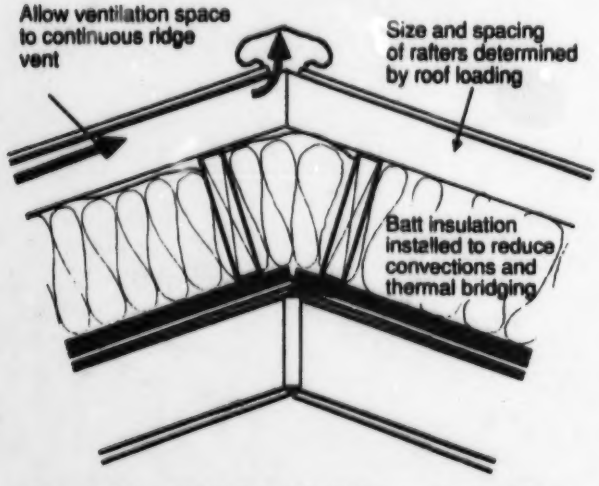


Fig. 10.24 Installing insulation and sheathing

Installation of the new insulation should be performed in a manner which restricts convective air movement and thermal bridging. The bottom batt can be laid horizontally over top of the polyethylene to span between the original sheathing and the underside of the new rafters. The next batt will be located between the rafters. The design must allow for a minimum of 50 mm clear air space between the top of the insulation and the top of the rafter.

Sheathing of the roof will follow standard roofing techniques. The sheathing should be cut short by at least 50 mm at the roof peak to allow for ridge venting. Soffitting at the eaves must also allow for the venting of each rafter cavity (Figure 10.25). Finishing details will follow standard construction practices.

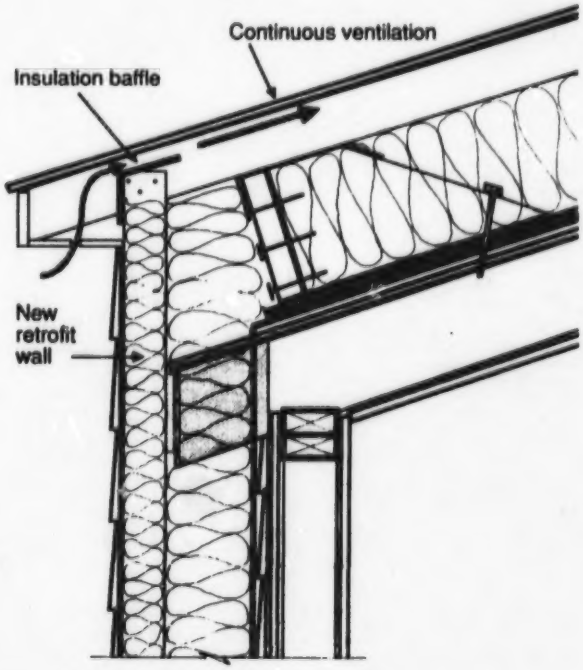


Fig. 10.25 Soffit detailing

11

VENTILATION AND HEATING SYSTEMS

The house which has been retrofitted to high levels of energy efficiency will have new demands and constraints placed on the house ventilation and heating systems. Airtight construction techniques provide the homeowner with a more comfortable, less drafty interior, with reduced potential for moisture-related problems. However, the contractor must understand that improvements to the building envelope will also affect the house mechanical systems: ventilation rates in the retrofitted house may prove unacceptably low; the supply of combustion air for the furnace may become insufficient; the reduced heating requirements may cause the furnace to overheat some areas of the house and underheat others. Major alterations to both systems may be required.

This chapter provides an overview of the need for controlled ventilation as part of a successful energy efficient retrofit which addresses air quality concerns without affecting householder comfort. It also addresses the requirements of an efficiently operating heating system, which will be capable of providing the homeowner with improved comfort levels in a safe and cost-effective manner.

While it is not assumed that the contractor will personally perform major work to the house mechanical systems, this chapter is organized to provide an overview of the design guidelines for efficient mechanical systems in a retrofitted house. It is hoped that the contractor will be better able to discuss these issues with the subcontractor performing the work. If the contractor does not have a particularly sound knowledge of mechanical systems, consultation with the HVAC contractor is strongly recommended. Any work performed on the house heating systems should be performed by fully trained personnel.

11.1 VENTILATION REQUIREMENTS

The introduction of outside air into the house is required for several reasons, including:

- control of odours, pollutants, and humidity levels within the house; and
- provision of adequate combustion air for fuel burning appliances within the house.

In conventional leaky houses the natural ventilation rate may be adequate to provide acceptable air quality through the dilution of odours, pollutants, and water vapour generated during normal household activities. As the house envelope is airtightened and the uncontrolled movement of air through the building envelope is reduced, the dilution effect is proportionally diminished. With increased airtightness, infiltration may be reduced to the point where insufficient ventilation will result. A strategy to provide controlled ventilation is an important element in the succesful design of a whole house retrofit.

Ventilation may be a problem throughout the heating season, or only during periods of relatively mild weather. Simple solutions may suffice (using existing exhaust systems, opening windows at certain times), or special ventilation arrangements may be required. What should be done depends upon the degree of airtightness achieved and the wishes of the owners.

If the house is very tight, with an equivalent leakage area (ELA) of 0.05 m^2 or less, as might be achieved by a comprehensive retrofit of the house envelope, the amount of air leakage will fall short of normal ventilation requirements much of the time. A properly designed, balanced ventilation system, capable of providing 0.5 air changes per hour (ach), as specified in R-2000 Guidelines, would currently be considered appropriate. This could involve the use of a heat recovery ventilator, depending upon the kind of investment the homeowner wishes to make. The ELA can be measured (see *CAN2-149.10-m, Determination of Airtightness of Building Envelopes by the Fan Depressurization Method)* if there is uncertainty about airtightness.

If the house after retrofit has an ELA in the vicinity of 0.05 to 0.1 m^2, it will be equivalent to many new houses being built according to current "good practice". Ventilation provided by air leakage will fall short of recommended levels during milder winter weather, especially with low wind, and a supplementary ventilation system providing a minimum of 0.3 ach on demand is desirable. It could consist, for example, of exhaust fans, properly installed, in bathrooms and the kitchen; or a properly designed fresh air supply duct connected to the return air plenum (with manual or automatic damper) where there is a warm air circulating system. The latter is not recommended for the tighter houses unless there is a good air barrier to prevent leakage of moist indoor air into the structure.

Where the ELA is likely to be above 0.1 m^2, typical of many looser houses currently being built, a supplementary ventilation system may be appropriate, but could be installed later if the homeowner finds that it is desirable. If the ELA is above 0.15 m^2, typical of many older houses and some still being built, infiltration will probably provide the minimum fresh air called for by current standards for essentially all of the heating season. This is also an indication that the whole house retrofit has not been successfully implemented.

11.1.1 Controlling Odours, Pollutants and Humidity

Odours are produced by cooking, cleaning, laundry, and homeowner hobby activities.

Pollutants in housing are emitted from a number of household products such as new building materials and home furnishings, soil gases entering the house through basement walls and floor slabs, household activities, and even from improperly operating combustion appliances.

Most Canadians are familiar with extremely low levels of humidity during the winter months. The low levels are seldom caused by a lack of moisture generation within the house since the typical family of four can generate as much as 10 to 20 litres of moisture per day. There is also the moisture which is stored in the house structure during the warmer months of the year. Since the tighter energy-efficient house has reduced natural ventilation rates, humidity levels will increase unless compensating steps are taken. High humidity may manifest itself in the form of surface condensation on windows and/or mould or mildew growth on cold surfaces.

The level of odours, pollutants and humidity in a house is dictated by the rate of generation and the rate of removal or dilution provided by the ventilation system. Therefore, control of odours, pollutants, and humidity levels may be attained by controlling the release of these products, and by exhausting these products through a ventilation system.

Control over the generation of moisture can be attained by turning off humidifiers, venting clothes dryers to the outside, and by resolving basement moisture problems. Likewise, the homeowner also has control over the generation of many of the odours and pollutants by allowing for ventilation of the products at the source of generation.

The ventilation system controls the level of odours, pollutants and excessive humidity by exhausting these at their source of generation and by the provision of outdoor air for dilution.

11.1.2 Combustion Air

Ventilation issues as discussed above all relate to the quality of the air in the home. A second but no less important issue relates to the **quantity** of air available in the home. Conventional fuel-fired furnaces and domestic hot water heaters connected to natural draft chimneys have traditionally depended on house air leakage for the supply of air required for combustion and venting. As house airtightness is increased, a point can be reached where air leakage will be inadequate for this purpose and venting failure can occur, discharging products of combustion into the house. The operation of exhaust fans can increase the possibility of venting failure.

If the house utilizes vented combustion appliances, provision should be made for combustion air in accordance with the applicable provincial codes. As a minimum, the requirements in the relevant fuel-burning equipment installation codes should be followed: *(CSA B139-1976 Installation Code for Oil Burning Equipment; CSA B365-1984 Installation Code for Solid Fuel Burning Equipment; CGA B149.1-M86 Installation Code for Natural Gas Burning Appliances and Equipment.)* These make a distinction between tight and average house construction. While not stated explicitly in all cases, an ELA of 0.05 m^2 or less is a practical definition of a tight house for this purpose, based on current practice. Special combustion air supply is required for tight houses but, for the most part, not for houses of average airtightness where air infiltration is regarded as sufficient.

R-2000 guidelines covering super-energy-efficient houses which have ELAs generally less than 0.03 m^2 do not permit the use of natural draft venting and call for appliances utilizing direct-vent (sealed), induced or forced draft venting systems. The direct-vent units take air for combustion directly from outside, while the induced or forced draft venting arrangements are less sensitive to house airtightness and have automatic shut-off in the event of draft failure. They represent another option for a retrofitted house. In any event, if the retrofit results in a relatively tight house, it is necessary to ensure that provisions for combustion air supply are adequate to ensure safe venting; if there is any doubt, a heating service contractor should be consulted.

Fireplaces, by competing for air, can contribute to venting failure of other combustion devices. As well, the airtightness of the house can affect the proper venting of fireplaces.

Fireplaces present a special venting challenge and potential danger in tight houses; R-2000 guidelines require that conventional fuel-burning fireplaces be equipped with tight-fitting glass doors and an outside air intake into the combustion chamber. Such provisions are desirable for any relatively tight house. At a minimum, the homeowner should be warned about the possibility of venting failure, particularly during the period when the fire is smouldering. The opening of a window at a lower level in the house in a space directly connected with the room containing the fireplace can provide the required combustion air.

11.2 VENTILATION SYSTEM DESIGN REQUIREMENTS

The design of an effective ventilation strategy for an energy efficient house must consider the following:

- the system must provide a ventilation rate which allows for good air quality under normal operating conditions, as outlined in 11.2.1;
- the system should be capable of removing odours, pollutants and humidity at their source;
- the system should be capable of distributing ventilation air to all rooms of the house;
- the ventilation system should provide fresh air in a manner which ensures homeowner comfort;
- the ventilation system should not increase the likelihood of combustion appliance backdrafting;
- the ventilation system should be installed and operated in a manner which minimizes energy costs; and
- controls for the ventilation system should allow for manual or automatic adjustments.

If the ventilation system is designed to meet the above-mentioned considerations, the homeowner will be provided with safe, comfortable interior air distribution. It is generally expected that the installation of a new ventilation system will be performed by an HVAC contractor, especially when the work is being performed in conjunction with alterations to the house heating system. The following considerations should influence the installation of the ventilation system:

- **The location** of the ventilation equipment should account for minimizing the amount of ductwork needed, minimizing the effects of vibration noises and allowing easy access to the equipment for servicing.

- **The controls** for the ventilation system should be set to ensure continuous operation of the system at a low speed. Either a manual or an automatic control should allow for speeding up the air flows. Most controls are based on humidity sensors.

- **The ductwork** should be installed in a manner which minimizes static pressure losses. Too many turns and bends can greatly reduce the amount of air being moved through the system. Any ductwork carrying cold air should be properly insulated and equipped with a vapour retarder to eliminate condensate build-up on the surface of the duct.

- **The supply grilles** should be designed to keep cold drafts away from the house occupants. This might mean the use of high side supply grilles, or floor grilles which direct air flows up the wall, rather than into the room.

11.2.1 Sizing the Ventilation System

The ventilation system should be capable of meeting specific requirements for fresh air supply. Most recommendations (including those in the National Building Code of Canada) are based on the need to install a system **capable** of providing a ventilation rate equivalent to 0.5 air changes per hour (ach) or 5L/s per room. For a house with a volume of 566 cubic metres the ventilation system must be capable of moving 283 cubic metres per hour.

The system is not required to be operating at this high a ventilation rate (0.5 ach) at all times. The system should be designed to provide a minimum continuous ventilation rate of somewhat more than 0.3 ach (air changes per hour), with the ability to kick into the higher ventilation rate as required.

11.2.2 Types of Ventilation Systems

Ventilation systems should be designed to avoid excessive pressure differences across the house envelope. High negative pressures can lead to a greater potential for the backdrafting of combustion appliances and can aggravate air quality problems caused by soil gas (radon). With high positive pressure, the potential for moisture problems in walls, windows and roofs is increased. Therefore, it is important that the house pressure remain relatively unchanged with the operation of the ventilation system. Ventilation systems can be categorized under three different modes of operation.

Exhaust only systems incorporate dedicated fans for exhausting the house air from locations such as the kitchen, bathrooms, laundry and workshops (see Fig 11.1). The house is operated under a slight negative pressure and fresh (make-up) air enters the house through leaks and gaps in the building envelope, or through specific inlet vents located around the house. To avoid high negative pressures, exhaust only systems must be designed to provide sufficient make-up air so as not to depressurize the house to the point where problems occur. If an inlet vent is provided, some form of tempering of the colder outside air should be provided.

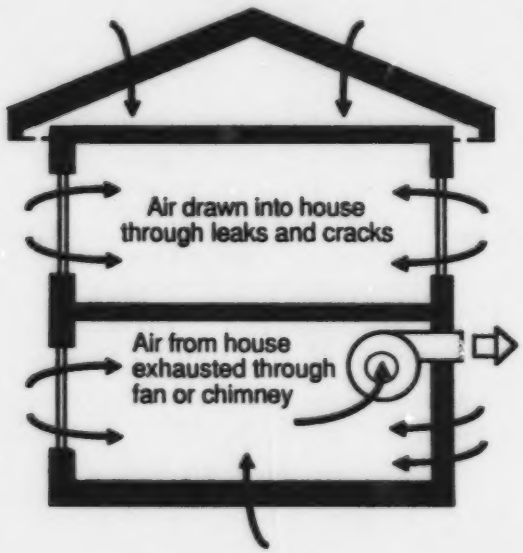


Fig. 11.1 Exhaust only systems

Supply-only systems utilize dedicated fans for bringing fresh air into the house, while exhaust air leaves the house either through leaks in the envelope or through specific outlet vents located throughout the house (see Figure 11.2). As the house will be operating under a positive pressure, the potential for moisture problems in its exterior walls and ceiling is increased. For these reasons and because of the difficulty in achieving acceptable comfort levels, supply-only ventilation systems are not recommended for energy efficient houses.

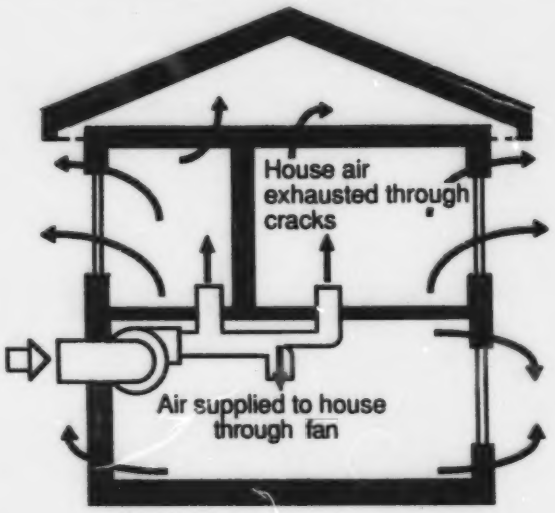


Fig. 11.2 Supply-only systems

Balanced ventilation systems count on both supply and exhaust fans to provide acceptable ventilation rates (see Figure 11.3). A balanced system implies that the same air flows are occurring on the exhaust and intake side of the system. A balanced system alleviates most of the difficulties associated with negative or positive pressures. The design and installation of the system must still account for the distribution of cold outside air through the incorporation of some pre-heating, or a mixing option which can provide the delivery of the fresh air at an acceptable temperature.

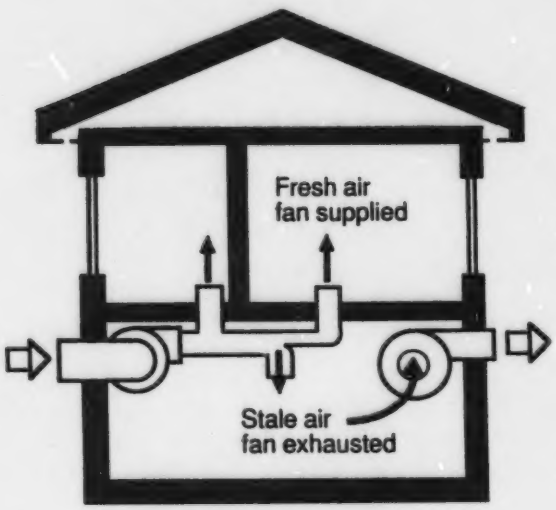


Fig. 11.3 Balanced-only systems

11.2.3 Tempering the Incoming Air

To avoid discomfort, the supply of fresh air should be tempered, or pre-heated. Several options are available which can temper the supply of fresh air, including the following:

- Heat recovery ventilators can recover heat from the exhaust air stream, and use the recovered heat to warm the incoming fresh air (see Figure 11.4). HRVs come pre-packaged with the controls and fans required for the system. A second advantage relates to the potential energy savings resulting from the recovery of the heat in the exhaust air.
- Preheaters can be installed in the fresh air intake duct to warm the incoming colder air. Usually these heaters are electrical elements or hot water coils.
- Cold outside air can also be warmed by mixing it with inside air. This can be accomplished, for example, by drawing the cold air into the cold air return of the warm air distribution system (see Figure 11.5).

The cost effectiveness of the installed system will need to be reviewed carefully by the contractor in association with the homeowner.

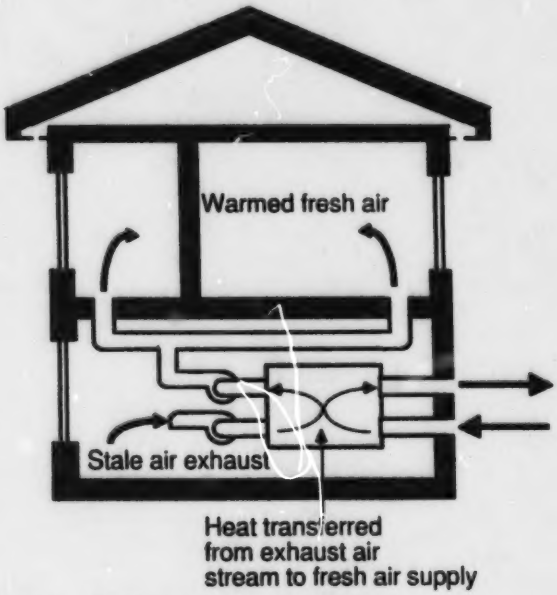


Fig. 11.4 Heat-recovery ventilation

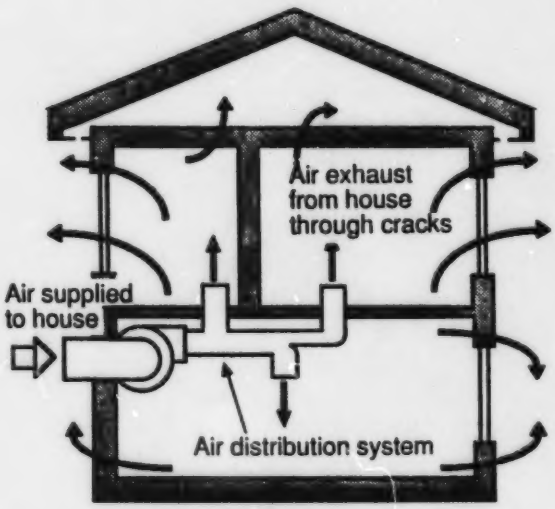


Fig. 11.5 Air supply system

11.3 IMPLICATIONS FOR THE HOUSE HEATING SYSTEM

The reduced heating load of the building will alter the demands on the heating system in several ways. Firstly, the heating system will be required for only a small fraction of its design capacity. This will mean that the furnace burner will be off for longer periods resulting in the potential for reduced seasonal efficiency. Secondly, the reduced heating load of the building may alter the heat distribution within the building. Finally, the tightened structure will result in less air being made available to the furnace for combustion purposes.

11.3.1 Heating Equipment

A major decision which will need to be made following the retrofit relates to whether the existing system should be upgraded or replaced. Any decision-making relating to the heating system should be premised on ensuring that the homeowner is provided with the highest levels of interior air quality and thermal comfort and that the system meets all regulatory requirements. The homeowner will be presented with two options. Either the existing heating system can be upgraded to accommodate the requirements of the retrofitted house or a new higher-efficiency furnace can be installed in its place.

The cost effectiveness of upgrading or replacing existing equipment should be assessed very carefully. The upgrading or replacement of heating equipment for the purposes of energy savings may not be justified in an energy-efficient retrofit as the house heating requirement is low, resulting in slower payback on the investment. For example, major improvements to the heating system may improve efficiency by 20%. In a house with a fuel bill of $1000, this translates to a saving of $200 a year. In an energy-efficient house, the same improvement on a fuel bill of $375 will only lead to a saving of $75.

The final consideration which the contractor and homeowner should understand is the supply of **combustion air** to fuel-fired combustion furnaces as discussed in 11.1.2. Conventional fuel-fired appliances in an airtight house should be supplied with a source of combustion air directly from the outside, following requirements of the relevant provincial codes. Many people involved in the field of energy-efficient housing will recommend that naturally aspirating combustion appliances not be permitted in an airtight house because of concerns relating to heating appliance backdrafting. If replacement of the existing system cannot be justified, the contractor must ensure that the question of combustion air supply has been resolved.

Table 11.1 summarizes the combustion air requirements of different appliances and demonstrates the reduced demands placed on the house with newer high-efficiency heating equipment.

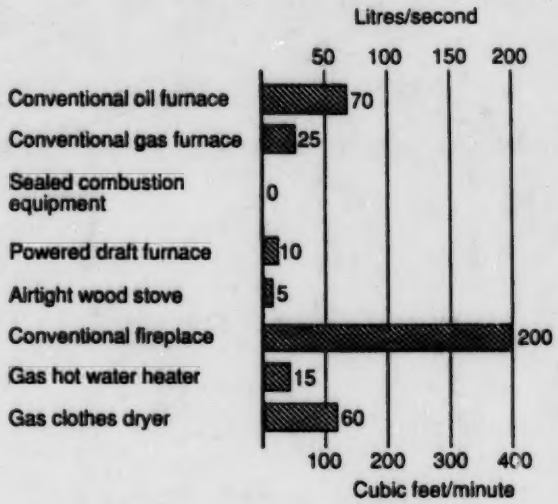


Table 11.1 Combustion air requirements

11.3.2 Furnace Upgrading and Replacement Options

Because of the nature of electric furnaces, improvements to these heating systems are limited to upgrading of the distribution system (see Section 11.4).

There are also few options for upgrading gas furnaces. However, there are available supplementary condensing heat exchanger units which may be added to existing gas furnaces to improve their overall efficiency.

With oil heating equipment, the contractor may consider efficiency improvements rather than the major expense of furnace replacement. Some of the measures which can be performed on an oil system include the following:

- downsizing of the burner nozzle reduces the amount of oil consumed and therefore reduces the amount of heat produced. Since most units are oversized, this will cause the burner to run longer and more efficiently;
- replacing the existing burner with a retention head burner improves efficiency;
- installing a delayed action solenoid valve improves furnace efficiency by improving the efficiency at furnace start-up; and
- replacing the existing oil burner with a natural gas conversion burner allows the existing furnace to burn natural gas rather than oil.

Replacement Options

The replacement of the existing heating system should be limited to those situations where the existing equipment is in poor condition or near the end of its service life. Heating equipment replacement for the purposes of energy savings is generally not justified in an energy-efficient retrofit.

If replacement of the existing heating system is desired, then the following factors should be considered:

- the type of fuel should be considered with regards to availability, price and the cost of installing new lines, storage or increased service; and
- the type of equipment required should be evaluated with regards to the type of fuel, combustion air requirements, cost, thermal efficiency, heat output, chimney modifications required, warranty and servicing claims, and the ease of installation.

Replacement heating systems in energy-efficient housing may include several options:

- medium and high-efficiency gas and oil furnaces;
- electric baseboard heaters and electric central forced air furnaces;
- electric heat pumps; and
- if the house has a central forced air heating system, an electric plenum heater. In traditional housing, these serve as supplementary heating sources. In an energy-efficient house they may serve as the prime heating source. The operation of this heater may be of benefit if other fuels are higher priced or if furnace replacement is required.

Further information on this topic may be found in the books available from Energy, Mines and Resources Canada, *The Billpayer's Guide to Heating Systems* and *Efficient Residential Oil-Heating Systems, A Manual for Servicemen, Designers and Builders.*

11.4 'TUNING' THE DISTRIBUTION SYSTEM

The contractor overseeing the upgrading of the house heating system should be aware of the potential benefits which will result from 'tuning' the heat distribution system. Whether the house is equipped with a central forced air system or a hydronic system, the effectiveness of heat distribution can be improved. Improvements mean better thermal comfort and reduced fuel consumption.

Tuning of a central forced air system may include several measures:

- adjusting the fan speed and its control;
- rebalancing the distribution system to reflect the retrofitted house;
- the taping of joints to prevent air leakage and, where ductwork passes through unheated spaces, the insulating of ducts; and
- assessing the location of floor registers and return air grilles.

Tuning of a hot water heating system may include these adjustments:

- installing or replacing a circulating pump;
- insulating of piping in cooler or unheated areas;
- ensuring that radiators are free of obstructions and that they allow clear circulation of air; and
- equipping radiators with thermostatically controlled valves which can result in greater temperature control on a room-by-room basis.

In all cases, upgrading of the system controls may be necessary.

11.4.1 Room Thermostats

The thermostat should be located where it is not subject to extreme conditions such as direct sunlight or cold outside air as this will have an adverse effect upon the operation of the heating system. The adjustment of the thermostat should be checked since this too will have a significant impact upon furnace operation.

If installation of a new thermostat is required or desired, a wide range of automatic devices are available. These devices can provide automatic temperature setbacks.

The occupant should also be advised about temperature setback, since lowering the indoor temperature in the house at night or during the day can often result in energy savings.

11.5 DHW HEATERS

The domestic hot water (DHW) system is the second largest energy user in the home, after space heating. It can also be affected by the whole house retrofit. Depending on how airtight the house is, the DHW system could have problems of combustion air supply similar to the problems for space heating systems identified in Section 11.1.2. Potential problems of combustion air can be solved by a number of means:

- installation of an electric DHW tank that does not require combustion air;
- installation of a DHW tank that draws combustion air from outside; or
- provision of outside combustion air.

However, a number of energy-efficient DHW tanks are available. If a tank is being replaced, consider the following points:

- some tanks have a higher insulating value than others. This is achieved by either increasing the insulation thickness or by incorporating a different type of insulation.
- some domestic hot water systems are integrated with a high-efficiency space heating system.
- there are electric heat-pump water heaters that collect heat from the basement air or from an exhausting stream of ventilation air.
- DHW systems that use outside combustion air operate at an efficiency about 20 per cent higher than a conventional tank.
- point-of-use water heaters, also called instantaneous water heaters, can be used to eliminate stand-by losses. These can work to advantage in situations, such as a remote bathroom, where the line losses and cost of plumbing increases the cost of a conventional system.

If the old DHW tank is being kept, and must be moved because of the renovation activity, there are many changes that can be made that will improve the energy efficiency of the system.

- The tank may be moved to a more central location with respect to the hot water lines of the house. This will decrease line heat loss and require less volume to deliver hot water to the fixture.
- The tank may be placed over a layer of rigid insulation to reduce heat loss to the basement slab.
- A heat trap may be installed at the hot water outlet of the tank (Figure 11.6).

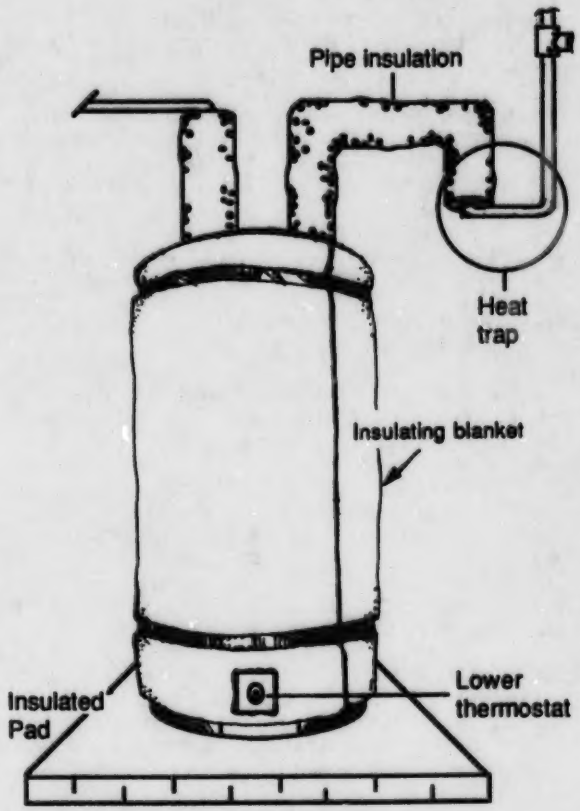


Fig. 11.6 DWH Tank, heat trap

Even if the existing tank is maintained in the same place, there are several ways to reduce hot water use and make the tank more efficient.

- Add an insulating blanket around the tank, ensuring that the thermostat covers of electric tanks, and the top and bottom of gas and oil tanks, are not blocked to ensure adequate combustion and dilution air.
- Insulate hot water pipes that go through an unheated space.
- Lower the water temperature in the tank by lowering the thermostat setting to 49°C – dishwashers may require a setting of 60°C.
- Install water saving devices, such as low-flow shower heads, in the house.

APPENDIX A: TECHNICAL REFERENCE

A.1 METRIC CONVERSION

A.1.1 Common Material Dimensions

Imperial	Metric	Nominal Insulation Value for given thickness (glass fibre batts) RSI Value	R Value
2 x 2	38 x 38 mm	.9	5
2 x 3	38 x 64 mm	1.4	8
2 x 4	38 x 89 mm	2.1	12
2 x 6	38 x 89 mm	3.5	20
2 x 8	38 x 190 mm	4.9	28
2 x 10	38 x 235 mm	7.0	40
2 x 12	38 x 286 mm	8.8	50
Rigid polystyrene (Type II)	25 mm	.7	4
Rigid polystyrene (Type IV)	25 mm	.9	5
2' x 8'	600 x 2400 mm		
4' x 8'	1200 x 2400 mm		
16" OC	400 mm		
24" OC	600 mm		
1"	25.4 mm		
1 1/2"	38.0 mm		
2"	51.0 mm		

A.1.2 Other Units

unit	to get	multiply	by
length	mm	inches	25.4
	m	feet	0.3048
area	m^2	ft^2	0.0929
		yd^2	0.836127
volume	m^3	ft^3	0.028317
		yd^3	0.764555
mass	kg	lb.	.454
flow	L/s	cfm	0.471947
energy	W	BTU/hr.	0.293072
insulation R value	RSI	R	0.1761
insulation R/unit thickness	RSI/mm	1 R/in.	0.0693
permeance (water vapour)	ng/Pas m^3	1 grain/hr ft^2	57.5
resistance to moisture flow	Pasm^2/ng	1h ft^2/grain	0.174

A.2 INSULATION VALUES

Building Material	RSI/mm (average)	RSI for thickness listed
Insulation		
Fibreglass batt	0.022	
Rock wool batt	0.023	
Fibreglass loose fill (blown-in type)	0.020	
Fibreglass loose fill (pouring type)	0.021	
Rock wool loose fill (blown-in type)	0.019	
Rock wool loose fill (pouring type)	0.021	
Cellulose Fibre, blown (settled thickness)	0.025	
Cellulose Fibre, poured (settled thickness)	0.024	
Expanded mica (vermiculite, zonolite, etc.)	0.016	
Polystyrene loose fill (shredded or beads)	0.020	
Expanded Polystyrene (rigid)	0.027	
Extruded Polystyrene (rigid)	0.035	
Polyurethane/Polyisocyanurate (rigid)	0.042	
Polyurethane (foamed in place)	0.042	
Fibreglass sheathing	0.031	
Wood Fibre	0.023	
Wood shavings	0.017	
Cork	0.026	
Glass fiber roof board	0.028	
Mineral aggregate board	0.018	
Compressed straw board	0.014	
Fibreboard	0.019	
Structural Materials		
Softwood Lumber (except cedar)	0.0087	
Cedar logs and lumber	0.0092	
Concrete		
2400 kg/m^3	0.00045	
1760 kg/m^3	0.0013	
480 kg/m^3	0.0069	
Concrete block (3 oval core)		
Sand and gravel aggregate		
100 mm		0.12
200 mm		0.20
300 mm		0.22
Cinder aggregate		
100 mm		0.20
200 mm		0.30
300 mm		0.33
Lightweight aggregate		
100 mm		0.26
200 mm		0.35
300 mm		0.40
Common brick		
Clay or shale, 100 mm		0.07
Concrete mix, 100 mm		0.05
Stone (limestone or sandstone)	0.00060	
Steel	0.000022	
Aluminum	0.0000049	
Glass (no air films), 3-6 mm		0.01

Building Materials	RSI/mm (average)	RSI for thickness listed
Air		
Enclosed air space (non-reflective)		
Heat flow up, 20-100 mm		0.15
Heat flow down, 20-100 mm		0.18
Heat flow horizontal 20-100 mm		0.17
Air surface films		
Outside air film (moving air)		0.03
Inside air film (still air)		
Horizontal, heat flow up		0.11
Sloping 45°, heat flow up		0.11
Horizontal, heat flow down		0.16
Vertical, heat flow horizontal		0.12
Attic air film		0.08
Roofing		
Asphalt roll roofing		0.03
Asphalt shingles		0.08
Wood shingles (cedar shakes)		0.17
Built-up membrane (hot mopped)		0.06
Crushed stone (not dried)	0.00055	
Sheathing Materials		
Softwood plywood	0.0087	
Mat-formed particle board	0.0087	
Insulating fiberboard sheathing	0.017	
Gypsum sheathing	0.0062	
Sheathing paper	0.00040	
Asphalt-coated kraft paper vapour barrier	negligible	
Polyethylene vapour barrier	negligible	
Cladding Materials		
Fiberboard siding		
Medium-density hardboard, 9.5 mm		0.10
High-density hardboard, 9.5 mm		0.08
Softwood siding (lapped)		
Drop (18 by 184 mm)		0.14
Bevel (12 by 184 mm)		0.14
Bevel (19 by 235 mm)		0.18
Plywood (9 mm)		0.10
Wood shingles		0.17
Brick (clay or shale), 100 mm		0.08
Brick (concrete and sand lime), 100 mm		0.05
Stucco, 25 mm	0.0014	0.03
Metal siding		
Horizontal clapboard profile		0.12
Horizontal clapboard profile with backing		0.25
Vertical V-groove profile		0.12
Vertical board and batten profile	negligible	
Interior Finish		
Gypsum board, gypsum lath, 13 mm	0.0062	0.08
Gypsum plaster		
Sand aggregate, 13 mm	0.0014	0.02
Lightweight aggregate, 13 mm	0.0044	0.06
Plywood, 7.5 mm	0.0093	0.07
Hardboard (standard), 6 mm	0.0053	0.03
Insulating fiberboard, 25 mm	0.017	0.42
Drywall, gypsum board, 13 mm	0.0061	0.08

Building Materials	RSI/mm (average)	RSI for thickness listed
Flooring		
Maple or Oak (hardwood), 19 mm	0.0063	0.12
Pine or Fir (softwood), 19 mm	0.0089	0.17
Plywood, 16 mm	0.0088	0.14
Mat-formed particleboard, 16 mm	0.0088	0.14
Wood fiber tiles, 13 mm	0.016	0.21
Linoleum or tile (resilient), 3 mm		0.01
Terrazzo, 25 mm	0.00056	0.01
Carpet, typical thickness		
Fibrous underlay		0.37
Rubber underlay		0.23
Windows (including some inside and outside air films)		
Single glass		0.15
Insulated glass (double pane)		
5 mm air space		0.25
6 mm air space		0.27
13 mm air space		0.30
19 mm air space		0.33
Insulated glass (triple pane)		
6 mm air space		0.38
13 mm air space		0.49
19 mm air space		0.50
Storm windows		
Single pane and 25 - 100 mm air space		0.35
19 mm insulated double pane with 89 mm air space		0.49

A.3 PERMEANCE OF COMMON BUILDING MATERIALS

Materials considered sufficiently resistant to the flow of water vapour to be used as vapour barriers are rated in terms of their permeance. The lower the permeance, the better the vapour barrier. The Building Code of Canada defines Type 1 vapour barriers as those with a permeance of 15 or less. Type 2 vapour barriers are those with a permeance of 45 or less.

Material	Permeance (ng/Pa-s-m^2)
Vapour Barriers	
.03 mm (1 mil) aluminum foil	1
.01 mm (.35 mil) aluminum foil	3
.10 mm (4 mil) polyethylene	3
.15 mm (6 mil) polyethylene	5
.05 mm (2mil) polyethylene	9
.05 mm (2 mil) unplasticized polyvinylchloride	38
.03 mm (1 mil) polyester	40
Asphalt kraft paper facing	43
Paint and Wallpaper	
2 coats asphalt paint on plywood	23
2 coats aluminum paint	29
1 coat latex vapour barrier paint	34
3 coats white lead/oil paint on wood siding	37
3 coats white lead/zinc oxide/oil paint on wood	53
vinyl wallpaper (normal thickness)	56
3 coats oil-based paint on wood	56
2 coats oil-based paint on plaster	111
3 coats latex paint on wood	500
ordinary wallpaper	1000
Insulations	
25 mm polyurethane	56
25 mm extruded polystyrene	36
25 mm expanded polystyrene	250
100 mm rock wool	1666
100 mm cellulose fibre	1666
100 mm fibreglass wool	1666
Other Building Materials	
100 mm glazed tile masonry	7
builder's foil	111
13 mm CDX plywood	29
5 mm asbestos-cement board	31
100 mm brick	56
200 mm concrete block	111
19 mm board (wood)	167
3 mm hardboard	500
6.8 kg tar paper	1000
plaster	1111
builder's sheathing paper	2500
gypsum drywall	3333
13 mm insulating board	3333
spun bonded polyolefin	5458

APPENDIX B: ANNOTATED BIBLIOGRAPHY

Title	**Insulating Basements, Crawl Spaces and Slabs-on-Grade**
Author(s)	Marbek Resource Consultants Ltd.
Publisher/Date	Energy, Mines and Resources Canada, 1987.
Available From	Natural Resources Canada 580 Booth Street Ottawa, Ontario K1A 0E4
Notes	This manual describes the techniques and effects of energy conservation measures for basements. It includes a review of structural considerations and the potential effects of soil and water mechanisms on both interior and exterior below grade insulation.

Title	**Humidity, Condensation and Ventilation in Houses**
Author(s)	National Research Council
Publisher/Date	National Research Council, 1984
Available From	National Research Council Ottawa, Ontario K1A 0R6
Notes	This booklet provides the text of presentations made by National Research Council staff during the Building Science Insight Series of 1983. It provides a very useful summary of the active processes involved in humidity and moisture problems, presented with some preventative measures. The booklet also includes a collection of the questions most frequently asked at the Insight Seminars.

Title	**Insulation Retrofit of Masonry Basements**
Author(s)	Timusk, John
Publisher/Date	Research and Development Section, Ontario Ministry of Municipal Affairs and Housing, 1981.
Available From	no longer available for purchase
Notes	This study offers a thorough treatment of the subject. It is particularly useful in that it discusses many typical foundation types encountered in retrofit work.

Title	**Major Energy Conservation Retrofits: A Planning guide for Northern Climates**
Author(s)	National Center for Appropriate Technology
Publisher/Date	U.S. Department of Energy, 1984
Available From	National Center for Appropriate Technology Po. Box 3838 Butte, MT 59702
Notes	This booklet provides an overview of technical and cost considerations involved in major retrofit work. It includes calculations of R-value and cost considerations for a number of sample wall assemblies.
Title	**R-2000 Builders' Manual**
Author(s)	The ETA Group
Publisher/Date	Canadian Home Builders' Association, January, 1987 edition
Available From	Canadian Home Builders' Association (see address below)

The following organizations publish a wide range of materials; contact them for a current publications list:

Canadian Housing Information Centre
Canada Mortgage and Housing Corporation
700 Montreal Road
Ottawa, Ontario
K1A 0P7

Telephone: (613) 748-2367; Fax: (613) 748-4069

Institute for Research in Construction
National Research Council
Ottawa, Ontario
K1A 0R6

Telephone: (613) 993-2607; Fax: (613) 954-5984

Canadian Home Builders' Association
150 Laurier Avenue West, Suite 200
Ottawa, Ontario
K1P 5J4

Telephone: (613) 230-3060; Fax: (613) 232-8214

APPENDIX C: GLOSSARY

Above Grade A term applied to any part of a structure or site feature that is above the adjacent finished ground level.

Adfreezing The process whereby wet soils freeze to below grade materials such as foundation walls or insulation, forcing movement of the material.

Air Barrier A material carefully installed within a building envelope assembly to minimize the uncontrolled passage of air into and out of a dwelling.

Air Change Per Hour (ach) A unit that denotes the number of times a house exchanges its entire volume of air with outside air in an hour. This is generally used in two ways: 1) under natural conditions and 2) under a 50 Pascal pressure difference. The R-2000 Home Program requires a house with 1.5 ach at 50 Pascals.

Air Leakage The uncontrolled flow of air through a component of the building envelope, or the building envelope itself, when a pressure difference is applied across the component. Infiltration refers to inward flowing air leakage and exfiltration refers to outward flowing air leakage.

Air Permeability The property of a building component to let air pass when it is subjected to a differential pressure.

Air Pressure The pressure exerted by the air. This may refer to static (atmospheric) pressure, or dynamic components of pressure arising from air flow, or both acting together.

Air Sealing The practice of sealing unintentional gaps in the building envelope (from the interior) in order to reduce uncontrolled air leakage.

Airtightness The ability of the house envelope to resist infiltration and exfiltration of air.

Ambient Temperature Temperature of the air, (1) outside the building, or (2) within a room.

Attic or Roof Space The space between the top floor ceiling and roof, and between a dwarf partition and sloping roof.

Automatic Flue Damper A damper added to the flue pipe downstream of a furnace or boiler and connected with automatic controls to the burner. Its function is to reduce heat loss up the chimney when the unit is not operating, consequently it provides the greatest savings during relatively mild weather when the furnace is on infrequently.

Backdrafting (flow reversal) The reverse flow of chimney gases into the building through the barometric damper, draft hood, or burner unit. This can be caused by chimney blockage or it can occur when the pressure differential is too high for the chimney to draw.
Balloon Framing A type of building construction in which the studs extend in one piece from the foundation sill to the roof plate.

Below Grade A term applied to any part of a structure or site feature that is below the adjacent finished ground level.

Building Orientation The siting of a building on a lot, generally used to refer to solar orientation which is the siting of a building with respect to solar access.

Building Paper A breather-type sheathing paper usually applied underneath or behind exterior finish material in wood-frame construction.

Casing A form of trim used around window and door openings.

Combustion Air The air required to provide adequate oxygen for fuel burning appliances in the building. The term 'combustion air' is often used to refer to the total air requirements of a fuel burning appliance including both air to support the combustion process and air to provide chimney draft (dilution air).

Condensation The transformation of the vapour content of the air into water on cold surfaces.

Conduction The transfer or travel of heat through a body by molecular action.

Convection Transportation of heat by movement due to the ascension of air or liquid when heated and its descension when cooled.

Convective Loops A type of air movement occurring in and around the building envelope caused by gaps in the insulation, weather barrier or air barrier.
Convector A heating device in which the air enters through an opening near the floor, is heated as it passes through the heating element and enters the room through an upper opening.

Controlled Ventilation Ventilation brought about by mechanical means through pressure differentials induced by the operation of a fan.

Curtain Wall A thin wall whose weight is carried directly by the structural frame of the building and which supports no compressive load other than its own weight.

Dampproofing The process of coating the interior or exterior of a foundation wall or floor to resist the passage of moisture through the wall or floor system.

Degree Day The number of degrees of temperature difference on any one day between a given base temperature and the mean day outside temperature. The base is usually 18 degrees C. The total number of degree days over the heating season indicates the relative severity of the winter for a specific location and is used in calculating heating requirements.

Dehumidistat An electronic sensing and control device used to regulate mechanical ventilation according to relative humidity in the building. When the relative humidity surpasses the preset limit, the dehumidistat activates the ventilation system to exhaust house air and bring in drier outdoor air.

Design Heat Losses A term expressing the total predicted envelope losses for a particular house design in a particular climate.

Dewpoint The temperature at which a given air/water vapour mixture is saturated with water vapour (i.e., 100% relative humidity). Consequently, if air is in contact with a surface below this temperature, condensation will form on the surface.

Dilution Air The air required by some combustion heating systems in order to isolate the furnace from outside pressure fluctuations and to maintain an effectively constant chimney draft.

Efflorescence The formation of a white crystalline deposit on the face of a wall caused by water leeching salts from the masonry.

Envelope The exterior surface of a building including all external additions e.g., chimneys, bay windows, etc.

Equivalent Leakage Area (ELA) The total area of all the unintentional openings in a building's envelope, generally expressed in square centimetres.

Exfiltration The uncontrolled leakage of air out of a building.

Expansive Soils Those fine grained soils such as clay, silt and fine sand which are frost susceptible and which are therefore more subject to frost heaving.

Fan Depressurization A large fan is used to exhaust air from a building in order to create a pressure difference across the building envelope; an analysis of the flow rate through the fan at different pressure differences provides a measurement of airtightness.

Frost Heaving The movement of soils caused by the phenomenon known as ice lensing or ice segregation. Water is drawn from the unfrozen soil to the freezing zone where it attaches to form layers of ice, forcing soil particles apart and causing the soil surface to heave.

Heat Recovery The process of extracting heat, (usually from a fluid) that would otherwise be wasted. For example heat recovery in housing generally refers to the extraction of heat from exhaust air.

HOTCAN A computer program for estimating the space heating requirements of residences. It is based largely on equations developed by the National Research Council, including calculations for home heat balance, below grade heat loss and solar gains through windows.

Hydronic Heating A heating system which uses hot water in the distribution system.

Impermeable Not permitting water vapour or other fluid to pass through.

Induced Draft Flue System A term referring to a type of gas heating system equipped with a fan downstream of the furnace. The fan pulls gases from the furnace and propels them to the outside, thereby eliminating the requirement for dilution air.

Infiltration The uncontrolled leakage of air into a building.

Internal Gains Heat gains to the home from lights, appliances and occupants.

Mechanical Systems A term widely used in commercial and industrial construction, referring to all the mechanical components of the building, i.e., plumbing, heating, ventilation, air conditioning and heat recovery.

Negative Pressure A pressure below atmospheric. In residential construction negative pressure refers to pressure inside the house envelope that is less than the outside pressure; negative pressure will encourage infiltration.

Orientation The direction with respect to point of the compass, in which building axis lie or external walls face.

Pascal A unit measurement of pressure. House airtightness tests are typically conducted with a pressure difference of 50 Pascals between the inside and outside. 50 Pascals is equal to 5.08 mm of water at 12.9 C.

Permeance Water vapour permeance is the rate of water vapour diffusion through a sheet of any thickness of material (or assembly between parallel surfaces). It is the ratio of water vapour flow to the differences of the vapour pressures on the opposite surfaces. Permeanre is measured in perms (m2 C/W).

Positive Pressure A pressure above atmospheric. In residential construction this refers to pressure inside the house envelope that is greater than the outside pressure; a positive pressure difference will encourage exfiltration.

Pressure Difference The difference in pressure of the volume of air enclosed by the house envelope and the air surrounding the envelope.

Radiant Heat Transfer The transfer of heat energy from a location of higher temperature to a location of lower temperature by means of electromagnetic radiation.

Relative Humidity The amount of moisture in the air compared to the maximum amount of moisture that air, at the same temperature, could retain. This ratio is expressed as a percentage.

Resistance Value (RSI) Thermal resistance value. A metric measurement of the ability of a material to resist heat transfer.

Sealants Flexible materials used on the inside of a building to seal gaps in the building envelope thereby preventing uncontrolled air infiltration and exfiltration.

Solar Heat Gain In passive solar heating a term referring to the amount of heat gained through windows over the heating season. Net solar gain refers to the solar heat gain less the heat losses through the windows.

Stack Effect Pressure differential across a building caused by differences in the density of the air due to an indoor-outdoor temperature difference.

ΔT A symbol used to denote temperature difference.

Thermal Break A material of low conductivity used in an assembly to prevent flow of heat by conduction from one side of the assembly to the other. Often used to refer to materials used for this purpose in the frame of metal windows.

Thermal Bridge A low thermal resistance path connecting two surfaces; for example, framing members in insulated frame walls or metal ties in cavity wall and panel construction.

Transmission Losses A term used to describe heat losses through the envelope resulting from the combined effects of conduction, convection and radiation.

U A symbol used to represent the conductivity of materials. The greater the U value, the better the material's ability to transfer heat by conduction.

Vapour Diffusion The movement of water vapour between 2 areas caused by a difference in vapour pressure, independent of air movement. The rate of diffusion is determined by 1) the difference in vapour pressure, 2) the distance the vapour must travel, and 3) the permeability of the material to water vapour. Hence the selection of materials of low permeability for use as vapour retarders in buildings.

Vapour Pressure The pressure exerted by a vapour either by itself or in a mixture of gases. For example, when referring to water vapour, the vapour pressure is determined by the concentration of water vapour in the air.

Vapour Retarder Any material of low water vapour permeability used to restrict the movement of water vapour due to vapour diffusion.

Waterproofing The process of coating a wall with a product or products designed to protect against continuous water pressure.

Weather Barrier The outermost assembly of the building envelope, used to protect the inner structure and insulation from the effects of wind and rain. Materials typically used are siding, building paper and flashing.

Wind Effect The effect of wind on the pressure difference across the house envelope and hence on air leakage rates.

APPENDIX D
CASE STUDIES

Appendix D contains five case studies of retrofit applications. The case studies are spread over the five geographic regions of the country

Case study 1

Whitehorse, Yukon
Log cabin: one storey with full basement
Built in 1972
167 m^2

Case study 2

Maidstone, Saskatchewan
One and one half story with three bedrooms
Built in 1920
76 m^2

Case study 3

Toronto, Ontario
Two-storey semi-detached frame
Built in 1881
121 m^2

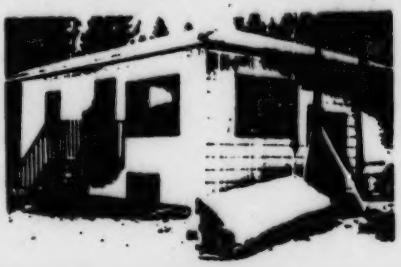
Case study 4

Verdun, Quebec
Multiple family unit
Built in the 1920's
710 m^2

Case study 5

St. John, New Brunswick
Wood Frame, Multi Family
Built in 1841
790 m^2

Case Study One



House Location	**Whitehorse, Yukon**
House Type	**Log cabin; 1 storey with full basement**
Other	
• constructed	**1972**
• size	**167 m²**
• degree days	**6,789**

House Component	Description – Before	Description – After
Basement	• Uninsulated	• RSI 2.6 extruded polystyrene added on the exterior
Walls	• Composed of logs approx. 175 mm diameter for an approx. RSI of 1.64	• Walls were caulked to seal against air leakage • Exterior of shell was wrapped in a polyethylene air-vapour barrier • Exterior curtain wall erected and insulated to RSI 4.9
Roof/Attic	• Uninsulated	• RSI 7.0 fibreglass insulation added
Windows	• A total of eight windows	• Windows upgraded by adding insulated liners to both basement and main floor
Doors	• 2 solid wood doors	• Doors were in good shape and only required weatherstripping
Heating System	• Oil furnace	• Oil furnace serviced and tuned • DHW tank insulated
Ventilation	• Air leakage before retrofit was measured at 5.89 air changes/hour at standard conditions of 50 Pa. pressure	• Air leakage after retrofit was tested at 3.20 air changes/hour at standard conditions of 50 Pa. pressure; a reduction of 45.7%.

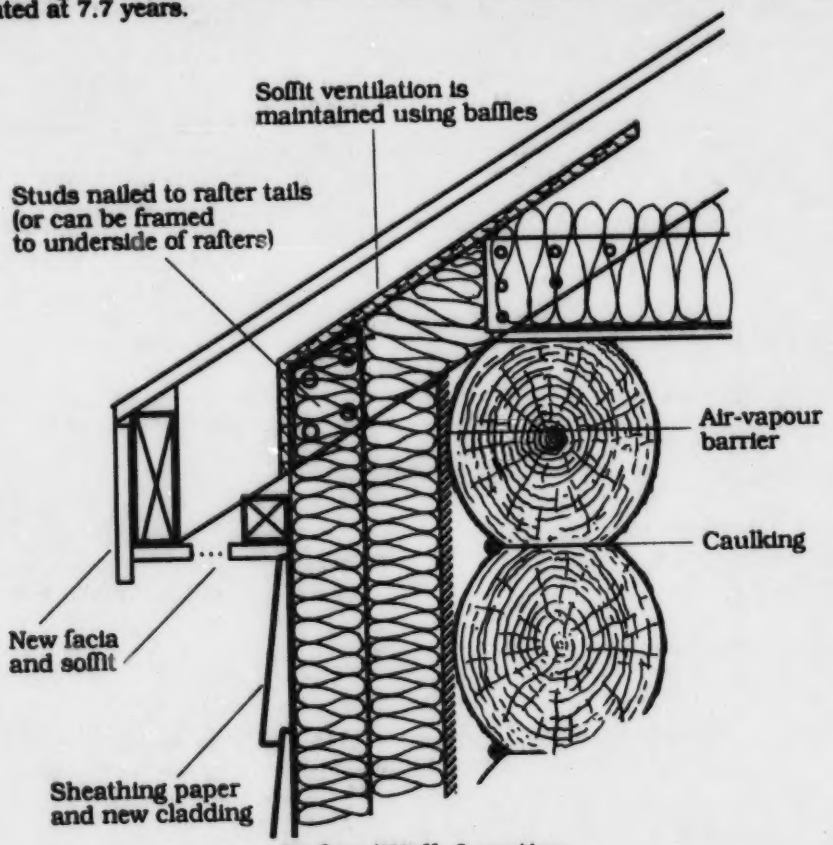
Retrofit Activity

Winters in the Yukon can be long cold affairs and despite the fact that wood has a fairly high RSI value for a naturally occuring substance, it would take logs over twenty inches thick to achieve an effective thermal resistance between RSI 5.0 and RSI 6.0. The owners of this particular log house had spent several winters in discomfort. Their major concerns were cold drafts, moisture problems, and high fuel bills (over $1,000 per year.)

An exterior retrofit was chosen for two distinct reasons: first, because of space limitations. Adding curtain walls to the inside of the cabin would have had too large an effect on available living space. The second reason was because of the ease of applying a continuous air-vapour barrier. By wrapping the walls from the exterior, the contractor avoided the problems that partition walls, stairs, and intermediate floors can pose.

The Whitehorse retrofit involved a total rewrap of the exterior shell of the house. A curtain wall composed of 38 x 64 mm lumber was held out from the old wall and two layers of insulation - the first horizontal, the second vertical - were installed.

Post retrofit analysis has shown that draft and moisture problems have been eliminated. The owners say that the building is much warmer and far more comfortable since the retrofit. Fuel bills have been reduced by approximately $770 per year. The total cost of the work was approximately $11,000. Discounting the cost of the new siding, the payback period has been estimated at 7.7 years.


Soffit ventilation is maintained using baffles
Studs nailed to rafter tails (or can be framed to underside of rafters)
Air-vapour barrier
Caulking
New facia and soffit
Sheathing paper and new cladding

Rafter/Wall Junction

Case Study Two

House Location: **Maidstone, Saskatchewan**

House Type: **One and a half storey frame house with three bedrooms**

Other
- constructed: **Built in 1920**
- size: **76 m^2**
- degree days: **6,000**

House Component	Description – Before	Description – After
Basement	• Uninsulated dug-out basement • Contains cistern and furnace	• Basement walls were wrapped on the interior with one layer of insulation (RSI 2.1) • Basement was isolated from living area by insulating floor joists of main floor to RSI 4.9
Walls	• Interior in poor condition; walls almost completely uninsulated	• Walls were stripped to reveal house frame: fibreglass batts (RSI 2.1) were installed • A 0.15 mm polyethylene air-vapour barrier was installed and all penetrations sealed
Roof/Attic	• Attic contained one room consisting of 25 mm diagonally-laid shiplap on 38 mm x 89 mm joists spaced 400 mm on centres. • Joist space uninsulated, except for a thin layer of sawdust	• Ceiling rafters were insulated and rafter ends were sealed with urethane foam • Blown-in fibreglass insulation was used to raise RSI value to 6.3 • Air-vapour barrier added to interior
Windows	• Windows in poor condition • Excessive number of windows	• New double-glazed sealed units replaced original windows • Windows considered as 'extras' (e.g., in the utility room) were removed and the space filled in and insulated
Doors	• Doors also in poor condition	• Doors replaced with new steel-insulated units
Heating System	• Oil furnace	• Furnace tuned, ducts insulated and hot air registers moved
Ventilation	• House relied on natural leakage to provide for ventilation requirements	• Air-to-air heat exchanger installed to improve household air quality

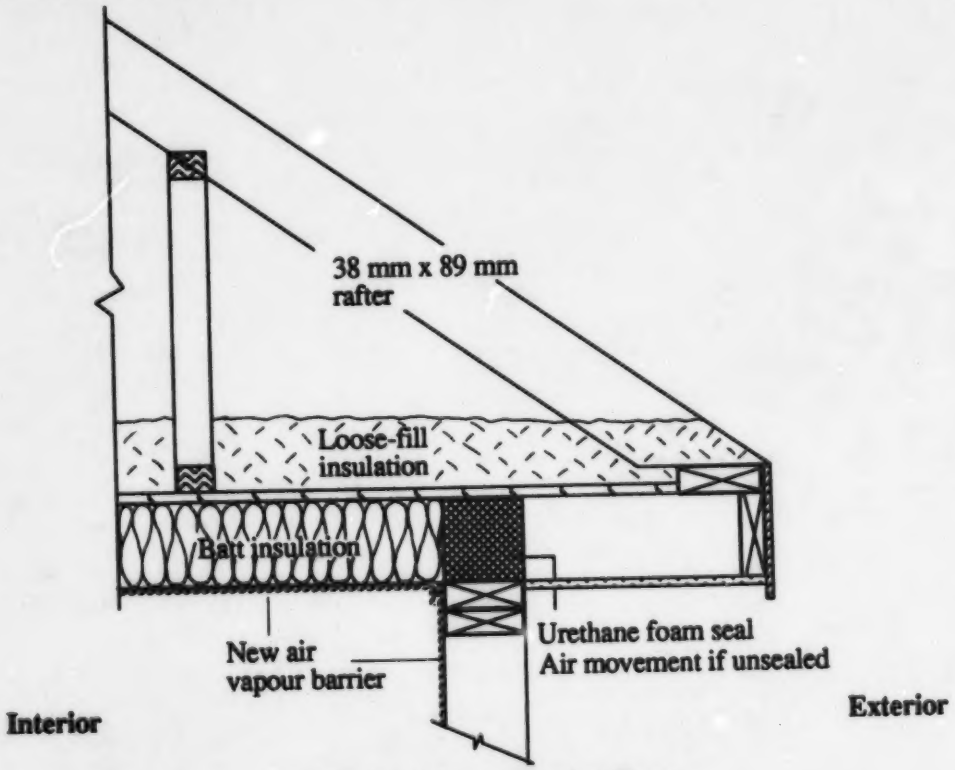
Retrofit Activity

The Maidstone house is almost seventy years old and required significant renovations to bring it up to modern standards. As with most older houses, air infiltration was the major problem. Consequently, the strategy in retrofitting this house was to place air sealing at the top of the list, followed closely by the upgrading of insulation levels.

The basement was thermally isolated from the main house by installing high levels of fibreglass insulation in the main floor joists. All heating ducts and water lines travelling from the basement to the living area were wrapped with insulation to prevent heat loss and freezing. Retrofitting the attic room was deemed too costly and time consuming and it too was thermally isolated from the main house.

An air-vapour barrier was added to the interior of the building as carefully and continuously as possible. This included tying window and door openings into the vapour barrier. All accidental and incidental penetrations were sealed. Polypans were utilized wherever electrical fixtures (e.g., electrical outlets, light fixtures) penetrated the barrier. An expanding urethane foam was used wherever the plastic could not reach. The original attic hatch, located on the interior of the shell, was sealed and insulated. Access to the attic was installed in the exterior.

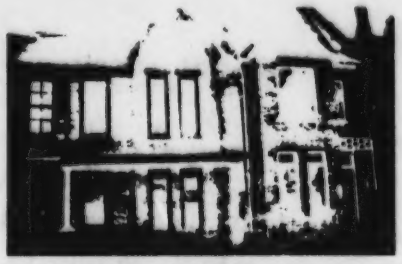
The total cost of the retrofit (labour and materials) was $10,522. Preliminary monitoring indicates that fuel consumption was reduced by almost 90 per cent. This represents a savings of almost $1,500 per year, and a simple payback period of 7 years.



Urethane Foam Seal at Eave

Case Study Three

House Location	**Toronto, Ontario**
House Type	**Two-storey semi-detached frame house**
Other	
• constructed	**1881**
• size	**121 m^2**
• degree days	**3,792**



House Component	Description – Before	Description – After
Basement	• Uninsulated brick foundation	• Below grade exterior retrofit at the rear with 100 mm of extruded polystyrene • The west wall was thermally linked to the neighbouring house
Walls	• Walls were uninsulated, although the building materials themselves provided some thermal resistance	• The restoration/renovation nature of the project demanded that each wall be treated in a different manner; this will be discussed more fully under 'Retrofit Activity'
Roof/Attic	• The attic contained RSI 1.0 of old mineral wool	• A continuous 0.15 mm air-vapour barrier was installed over the ceiling joists and sealed to blocks of rigid insulation at the eaves and gables • RSI 10.8 of cellulose insulation was then blown into the area
Windows	• Original windows in relatively good condition, complete with exterior storms	• Three ill-fitting basement windows were blocked and insulated • One south-facing window in poor condition was replaced by a triple-paned unit with an awning ventilator section
Doors	• Original solid-wood doors in fair shape but poorly weatherstripped	• The original front (north facing) double entry was retained; weatherstripping was upgraded • The south door was replaced with an insulated-core steel door with magnetic weatherstripping
Heating System	• Old, oversized oil furnace • Gas water heater	• The oil furnace was replaced by a medium-efficiency, induced-draft gas furnace • Electric water heater installed, closer to point of use
Ventilation	• House originally ventilated by natural leakage. Total cracks and holes in the structure added up to an opening of aproximately 0.42 m^2	• An air-to-air heat exchanger was installed one year after the retrofit work was complete (pre-ducted) • The attic space was left to vent naturally through the leaks and cracks in the gable ends

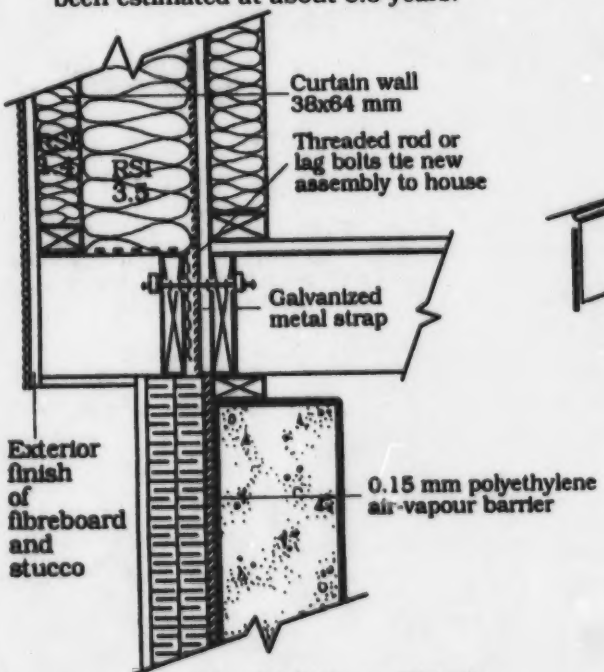
Retrofit Activity

Located in downtown Toronto this 100-year-old Victorian home was in need of renovation, restoration and retrofitting. The owners, however, wished to maintain as many of the original architectural features as possible. Consequently, the energy-efficient features introduced into the home were dictated by the restoration activities.

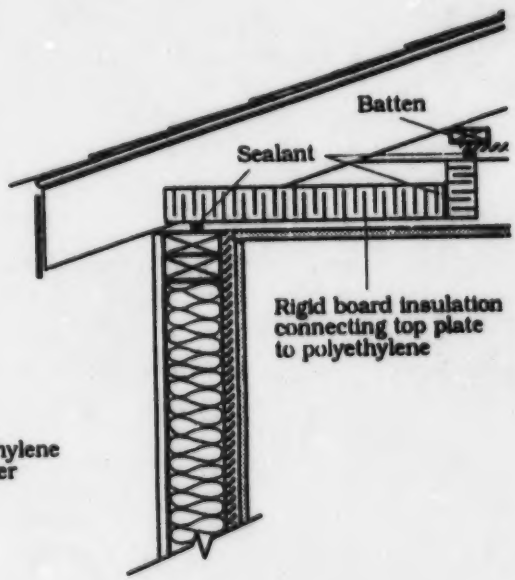
Upgrading the thermal capacities of the attic and basement provided no difficult problems (beyond having to work in cramped, tight quarters). The walls, however, provided several unique challenges. The north wall was insulated by blowing cellulose fibre into the stud cavity. A total of RSI 2.8 was installed. This approach was chosen because of the need to preserve both the interior and exterior details. Two coats of enamel paint on the interior provided the vapour retarder, while weatherstripping and caulking provided an air barrier.

The south wall was first covered with a 0.15 mm sheet of polyethylene, caulked, and secured at seams with battens. A curtain wall of 38x64 mm was fitted into place a total of 190 mm out from the wall and two layers of glass fibre insulation (RSI 4.9) installed. A four-coat stucco finish was then applied. The east wall is a frame party wall and no thermal upgrading was necessary. The west wall was separated from the neighbouring house by about 1 m. Rather than insulating the wall, it was connected to the neighbouring unit by means of a "thermal link". This involved constructing an insulated roof section (at the attic level) and insulated wall ends. RSI 10.4 fibreglass batts were installed at ceiling level. The end walls were filled with RSI 4.2 batts, plus 50 mm of high density-expanded polystyrene. Insulated core doors were installed at either end to maintain access from front to back. The house is thermally linked to its neighbour and has minimum heat loss.

The total cost of the retrofit aspect of the renovation was under $10,000. Reduced envelope heat loss and improved furnace efficiency combined to reduce heating costs by 80-90 per cent (from $1600 per year to less than $200.). The payback has been estimated at about 6.5 years.

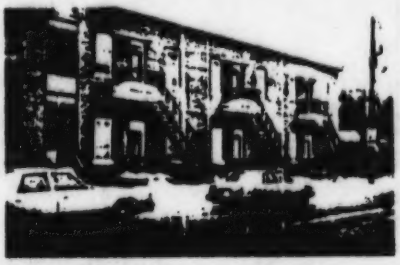


Curtain Wall Base Detail



Soffit Detailing

Case Study Four



House Location	**Verdun, Quebec**
House Type	**Multiple-Family unit**
Regional Specifics	
• constructed	**Built in the 1920's**
• size	**710 m^2**
• degree days	**4,471**

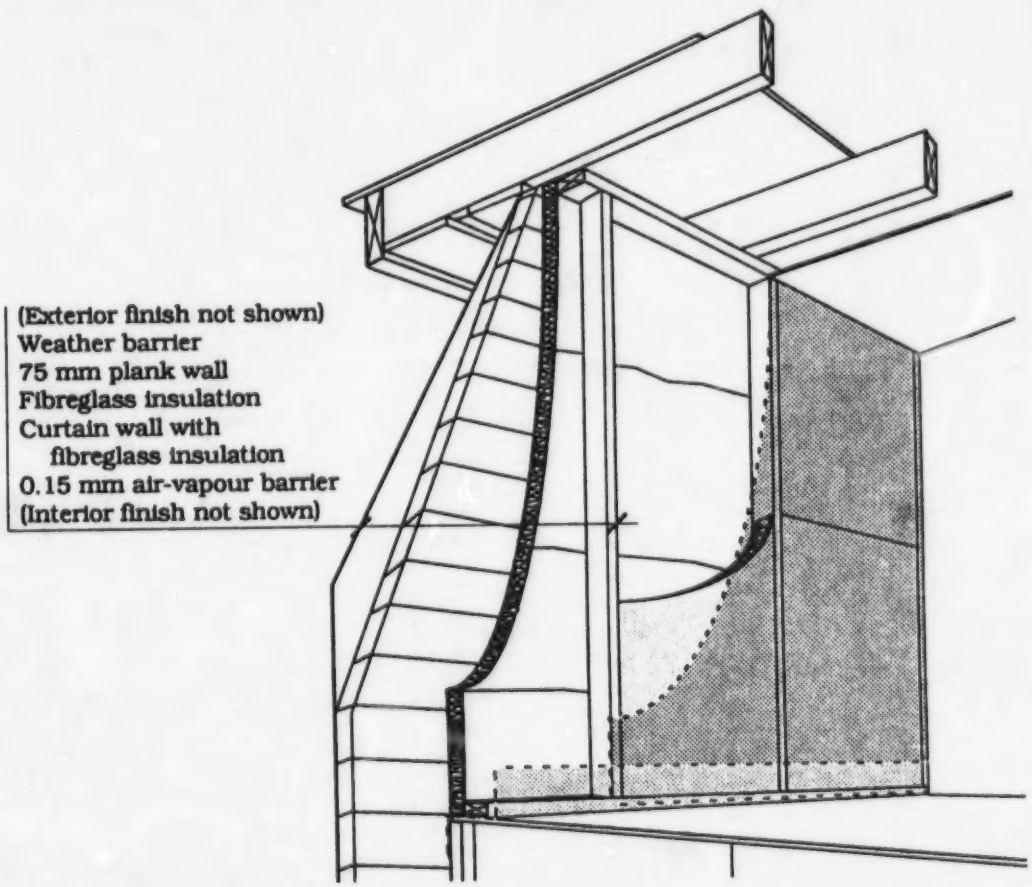
House Component	Description – Before	Description – After
Basement	• 1 m crawl space uninsulated • Fieldstone foundation	• 38 mm of urethane insulation • 0.15 mm polyethylene air-vapour barrier
Walls	• Brick veneer; building paper; 64 mm solid plank frame; 18 mm furring; lath and plaster	• Lath and plaster were removed • A 38 x 64 mm interior curtain wall was added 38 mm from the plank wall to accomodate new insulation
Roof/Attic	• Roofing membrane; 18 mm deck; space; 18 mm deck; joists; lath and plaster	• 250 mm of fibreglass added between joists for a total of RSI 5.28 • Polyethylene air-vapour barrier added on the warm side of the insulation and covered with gypsum board
Windows	• Double aluminum guillotine inserts of poor quality and in poor condition	• Double-hung windows with aluminum frames and thermal breaks were installed
Doors	• Front door was composed of 45 mm wood frame with single glazing • 2 Rear doors composed of 45 mm wood frame with single glazing	• 45 mm mortise and tenon type doors with thermopane glazing and factory-installed weatherstripping replaced the original doors
Heating System	• Gas wall furnace	• Electric baseboards were installed
Ventilation	• None	• Kitchen and bathroom fans were added

Retrofit Activity

The Verdun Units were built in the 1920's and like many homes of this era contained little more than the structural components for insulation. An interior retrofit was chosen since the brick veneer was in relatively good condition and the cost of replacement was prohibitive. Further, the insulation upgrade was part of a larger renovation effort. Much of the plank in the walls had rotted due to severe moisture. In one case, the entire rear plank wall had to be reconstructed using 38 x 138 mm studs to accomodate an increased amount of insulation.

The retrofit involved erecting a 38 x 64 mm interior curtain wall 200 mm from the existing exterior wall. By spacing the wall out it was possible to install two layers of insulation. The first was laid horizontally between the plank wall and the curtain wall. The second was installed vertically in the stud space provided by the new frame wall for a total of RSI 2.8. This 'cross-hatching' of the insulation has the added effect of reducing potential air passages through the thermal envelope. An air-vapour barrier was installed on the interior of the frame wall and finished with gypsum board.

Projected annual heating costs for most of the units have been estimated at less than four hundred dollars.



Interior Retrofit

Case Study Five

House Location	**St John, N.B.**
House Type	**Wood Frame, Multi-Family Dwelling (6 units)**
Other	
• constructed	**1841**
• size	**780 m^2**
• degree days	**4768**

House Component	Description – Before	Description – After
Basement	• Concrete and rubble walls with cedar posts on concrete pads • No insulation in joist space	• Repaired rubble walls with new PTW posts on concrete pads • Joist space was cleared and filled with RSI 7 of blown-in fiberglass and sealed with an air infiltration barrier
Walls	• Wood frame – UFFI foam in approx. 80 per cent of wall cavity	• Blown-in fibreglass blanket to RSI-3.5 • Upper storey wall furred out to accept 150 mm fibreglass batts • 0.10 mm air-vapour barrier sealed with acoustical sealant
Roof/Attic	• Wood frame – no insulation	• New roof installed • 150 mm fibreglass batts installed (RSI-3.7) • Blown-in wool (RSI-5.6) in flat roof area
Windows	• Wood, double-hung, single-glazed	• New, double-hung units installed; double-glazed thermal pane; frame sealed to air-vapour barrier • Jamb spaces filled with expanding foam insulation
Doors	• Wood panel	• New, insulated metal doors complete with 'foam-guard' weather-stripping installed with self-closing devices
Heating System	• Oil fired space heaters, one per unit	• New electric baseboard resistance heating complete with individual line voltage thermostats
Ventilation	• Operable windows	• 60 l.p.s. mechanical exhaust fans, one per bathroom and kitchen • Operable windows

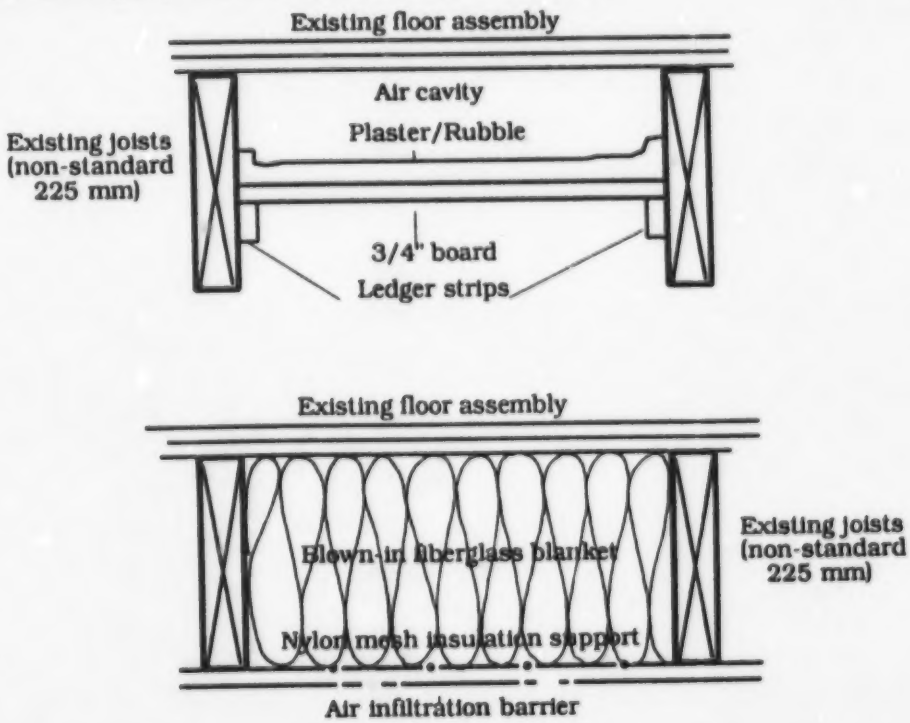
Retrofit Activity

One hundred and forty-six years of age, this building in St. John, New Brunswick was due for some renovations: new wiring; new plumbing; new doors and windows; a new addition; and the removal of UFFI from the wall cavities. The work was of such an extensive nature, that 'piggybacking' a retrofit onto the project was not going to add significantly to the overall cost.

Once the UFFI was removed, the wall cavities were refilled with fiberglass batts and a 'blown-in fibreglass blanket'. Blown-in insulation was utilized since most of the stud cavities were irregular and would not accept conventional batts. Furthermore, the blown-in fibreglass has a higher RSI value than the batts and contains a latex adhesive that bonds the glass fibres to each other as well as the studs, to prevent settling.

Energy-efficient windows and doors (twelve in all) were installed, and a 4 mil sheet of polyethylene, caulked and made as continuous as possible, completed the retrofit work. Heating costs prior to the retrofit – with the UFFI still in place – were estimated at $10,130 per year. After retrofit estimates put the new heating costs at $6,000, almost a fifty per cent reduction in heat loss.

The diagram below details how the crawlspace was effectively isolated from the thermal envelope. In the first floor joist an additional layer of lath and plaster had been installed in part to cut down on air infiltration, and in part to create a dead air space for insulative purposes. This is quite common on the east coast for houses of this vintage. However, it had lost what little effectiveness it once had over the years. The plaster was removed to allow insulation to be installed. The underside of the insulation was covered with an air infiltration barrier, preventing cold air from penetrating the insulation while allowing any moisture in the joist space to pass out.



Isolating the Crawlspace

APPENDIX E
REVIEWERS

The authors wish to thank the following persons:

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Canadian Home Builders' Association

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Alberta Agriculture

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Federal Pioneer Ltd., Toronto

Peter Barclay
National Energy Conservation Association

Keith Bryant
Enerplan Consultants, Toronto

Fran Cameron
Canada Mortgage and Housing Corporation

Bob Charest
Canadian General Standards Board

Tom Cochren
Mr. Renovator, Hamilton

Dave Coon
Conservation Council of New Brunswick

Wayne Cullum
Westroc Industries Ltd., Mississauga

Darwin Curtis
The New Brunswick Energy Secreteriat

B. Darrah
Society of the Plastics Industry

Sylvia Davis
Ontario Ministry of Housing

John DeGrace
Department of Energy and Forestry, PEI

Jacques Desbiens
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ACKNOWLEDGEMENTS: CASE STUDIES

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